ENVIROMENTAL
MONITORING COMPONENT 2001

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NOAA/USAID Small-Scale Shrimp Producer Technical Assistance Program for Nicaragua

Environmental Monitoring Component

Final Report

By

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EXECUTIVE SUMMARY

Shrimp aquaculture in the Estero Real system of Nicaragua has developed rapidly during the past decade, with nearly 9,000 ha in production in 2000. This represents about 47% of the area identified as appropriate for shrimp farm development in a 1994 PRADEPESCA study. Area in production dropped by 25% following Hurricane Mitch. The industry is recovering from the impact of the hurricane and subsequent outbreak of white spot syndrome virus. Continued successful development of shrimp aquaculture in Nicaragua must minimize environmental impacts and occur within the assimilative capacity of the Estero Real.

Many diverse groups in Nicaragua (Administración Nacional de Pesca y Acuicultura [ADPESCA], Asociación Nicaragüense de Acuicultores [ANDA], Ministerio Agropecuario y Forestal [MAGFOR], Ministerio de Ambiente y Recursos Naturales [MARENA], Ave Maria College of the Americas, Centro de Investigación de Ecosistemas Acuáticos, Universidad Centroamericano [UCA/CIDEA], and Cooperative Unions) have a strong interest in a water quality monitoring program in the Estero Real system as it relates to the development of shrimp aquaculture.

The rapid growth of shrimp aquaculture in Nicaragua, the potential for its future growth, and increased environmental awareness have raised concerns that the combined effluent from shrimp ponds might accumulate in such concentration as to contaminate waters of the Estero Real system as a source of water for shrimp aquaculture. Over-development of shrimp aquaculture has occurred in other coastal regions of the world, with disastrous consequences for the industry. Consequently, it is important to determine whether the Nicaragua shrimp aquaculture industry has reached a self-limiting level of development and to quantify its magnitude. This is known as the *assimilative capacity* or *carrying capacity* of the system. It is important to recognize that carrying capacity of an estuary is not a single number, but is, in fact, a function of position, both in terms of the region of the watercourse in which acceptable water quality must be maintained, and in terms of the actual locations of the sources of contamination. Furthermore, there is not a unique value for carrying capacity, in terms of numbers and sizes of discharges (e.g., shrimp farms), because different spatial distributions combined with different effluent loads can result in the same impact on water quality. If the combined effect of a collection of effluent loads is to reduce water quality below its acceptable value, then it can be said that the carrying capacity of the system has been exceeded. It must be noted that nutrient loads to the estuary originate from a variety of sources, including river discharge, urban and industrial discharges, shrimp farm discharge, agricultural and watershed runoff, and mangrove forest litter.

Through the *NOAA/USAID Small Shrimp Producer Assistance Program for Nicaragua: Environmental Monitoring Component*, a water quality monitoring program for the Estero Real system was designed in consultation with the NOAA Consultative Group for Aquaculture. The goal of the monitoring program is to achieve sustainable development of shrimp aquaculture in Nicaragua through knowledge of estuarine water quality to benefit of the environment and socio-economic development. Objectives of the program are:

- To establish a water quality monitoring program in the Estero Real.

- To create a database of water quality variables for the Estero Real against which future data can be compared, and that can be used by all stakeholders in decision making regarding future development and management of shrimp aquaculture.
- To initiate the collection of data needed to estimate the Estero Real assimilative capacity (carrying capacity). Estimation of the Estero Real assimilative capacity is possible only if a specific follow-on project is funded; this activity exceeds the scope and budget of the current project. However, data can be collected as part of the current project that will facilitate completion of a future project to estimate assimilative capacity of the Estero Real.
- To involve all stakeholders, be they from the public, private or university sectors, in the Estero Real estuarine water quality monitoring program.
- To estimate nutrient budgets for extensive and semi-intensive shrimp production systems in earthen ponds.

Future changes in water quality variable concentrations at different sample stations along the Estero Real only can be detected by comparison against baseline data. In an ideal situation such baseline data would be collected beginning one to two years before initiation of any shrimp culture activities in the estuarine system. However, in Nicaragua the reality is that shrimp culture industry development already is well underway. Thus, the estuarine water quality baseline must be established for the prevailing level of development. It is known that season affects estuarine water quality variable concentrations because of evaporation, and changes in river discharge and watershed runoff. Also, annual variation of seasonal effects can be substantial. Therefore, it is recommended that two years of data collection comprise the baseline of water quality variable concentrations for the Estero Real system. Such an approach is similar to the one taken in Honduras, where the estuarine water quality monitoring program began in 1993 and continues to date.

Because of its demonstrated capabilities and extensive experience in estuarine water quality and shrimp aquaculture, the Centro de Investigación de Ecosistemas Acuáticos, Universidad Centroamericana, was selected to implement the Estero Real estuarine water quality monitoring program.

The estuarine water quality monitoring program began on a limited basis January 2001 and was expanded to a bi-weekly sampling effort in late May 2001. Water samples were collected at 14 sites within the Estero Real system: twelve sites were along the main channel of the Estero Real and extended from El Chorro, near the mouth of the Estero Real, to the Puente Estero Real on the Chinandega-Guasaule highway. One sample station was located in each of the Dos Aguas Grandes and Dos Aguitas estuaries. Water samples were analyzed for 14 nutrient and 5 microbiological variables.

Data collected during 2001 showed that dissolved oxygen (DO) concentration at 0.5 m depth was high (5-7 mg/L) near the mouth of the Estero Real (El Chorro sample station), and declined with distance upstream. There was a DO sag, i.e., DO concentrations < 1 mg/L, generally observed from the FRIXSA to the La Polvosa sample stations. At the Puente Real sample station, DO concentration generally was recovering and ranged from 1-4 mg/L. While there is no single value of DO that demarcates acceptable from unacceptable water quality, as a general rule concentrations in excess of 5 mg/L assure maintenance of almost all aerobic species, and only the most resilient can survive with DO's below 2 mg/L for long periods of time. Occurrence of DO's below 1 mg/L for any substantial period of time will eliminate most higher aerobic forms.

Salinity concentration at 0.5 m depth generally was near 35 g/kg at the El Chorro sample station, and generally remained constant up to the Dos Aguitas sample station. At sample stations above Dos Aguitas salinity often dropped off to near 0 g/kg; the rate of decline varied from one sampling to the next, likely being affected by the volume of river discharge and watershed runoff entering the Estero Real. Most of the field sampling that was accomplished took place during the rainy season, so regions of low salinity were expected along the Estero Real.

While determination of the assimilative capacity of the Estero Real exceeded the scope and budget of the current project, collection of some of data critical to this determination was initiated as part of the current project. The bathimetry of the main channel of the Estero Real, and parts of the Dos Aguas Grandes, Dos Aguitas, and El Chorro estuaries was mapped using a recording fathometer. Dissolved oxygen/temperature/salinity vertical profiles and current velocities were measured monthly at sample stations along the Estero Real main channel. Relative tide height was measured periodically at four stations along the Estero Real main channel. Immediate application of data collected as part of the current project will be to increase understanding of dissolved oxygen/temperature/salinity vertical profiles, current velocities, estuarine bathimetry, and relative tide heights along the Estero Real. However, real use of data collected during the current project will be determination of Estero Real assimilative capacity, which only is possible in a future, independently funded project.

Dissolved oxygen/temperature/salinity profiles were measured *in situ* monthly from June through November 2001 at the 11 stations along the Estero Real main channel during consecutive high and low (or low and high) tides. Data showed that the same DO sag observed in surface water samples was present throughout the water column. Salinity was highest in the main channel of the Estero Real during August 2001, and lowest during October 2001. Salinity decreased in the monthly samples from August to October in the following order: July, June, September, and November.

Most shrimp culture in Nicaragua is conducted at a semi-intensive level of management. Stocking rates of shrimp into ponds are low (5-30 PL/m^2). Little or no water is exchanged in ponds (to maintain water quality) during shrimp grow out. And, exogenous nutrients in the form of formulated feeds, and sometimes chemical or organic fertilizers, are added to ponds to increase shrimp productivity. While some of the exogenous nitrogen and phosphorus are assimilated as shrimp flesh, adsorbed by the pond soil, or otherwise metabolized by the pond biota, the remainder of the added nitrogen and phosphorus are discharged to the environment during water exchange events or during pond harvest. Nutrient budgets were developed for aquaculture ponds to quantify inputs and outputs, on a mass basis, of nitrogen and phosphorus.

Nitrogen input as feed and fertilizer ranged from 2,97 – 17.68 kg/ha, while the range for phosphorus was 0.79 – 4.68 kg/ha. Harvested shrimp removed 1.49 – 8.78 kg/ha of exogenous nitrogen and 0.18 – 1.03 kg/ha of exogenous phosphorus. The shrimp harvest accounted for 34 – 199% of nitrogen added as feed and fertilizer, and for 11 –75% of phosphorus added as feed or fertilizer. Shrimp accounted for a greater percentage of feed and fertilizer nitrogen and phosphorus in cooperative farm ponds because of the lower quantities of added nutrients. In the more intensively managed ponds at the UCA-CIDEA farm, added nutrients were not assimilated as efficiently by shrimp, most likely because of the relatively low gross shrimp yield. The un-recovered nitrogen most likely was discharged from the pond at draining, entering the estuary. The un-recovered phosphorus most likely was adsorbed to pond mud and discharged to the estuary during draining.

Recommendations

1. The estuarine water quality monitoring program implemented by the Centro de Investigación de Ecosistemas Acuáticos, Universidad Centroamericano (UCA-CIDEA) during this project should be continued for a minimum of two to three full years (at least two additional years beyond the work accomplished during this project) in order to establish fully the baseline database. An estimated annual budget of US $100,000 is necessary from a donor such as USAID.
2. It would be desirable to determine dissolved oxygen/temperature/salinity profiles on a monthly basis in Nicaraguan territorial waters of the Gulf of Fonseca, particularly off the mouth of the Estero Real. However, in order to accomplish this, UCA-CIDEA must have a more sea-worthy boat to ensure the safety of the field crew.
3. Once two and one half years of data have been collected, UCA-CIDEA should contract with a specialist in estuarine modeling to develop a carrying capacity model for the Estero Real. Dr. George Ward, Center for Research in Water Resources, University of Texas at Austin, is recommended for this activity because he developed the carrying capacity model for the San Bernardo and El Pedregal estuaries in Honduras and is knowledgeable about the shrimp industry in the region.
4. It is recommended that USAID/Nicaragua fund the activities outlined in these recommendations because project results will provide necessary data to public and private sector planners to develop an environmentally sound economic development plan for the Estero Real. The estimated cost of a two-year project is US $250,000 ($75,000 annually for the monitoring program, $30,000 for a sample boat/motor, $70,000 for carrying capacity model development).

INTRODUCTION

The Estero Real, a large deltaic estuarine system of the Gulf of Fonseca, is the focus of shrimp aquaculture development in Nicaragua. The Gulf of Fonseca is a large estuarine embayment on the Pacific coast of Central America that spans the countries of Nicaragua, Honduras, and El Salvador. The low relief of the region, consisting of salt flats fringed by mangrove swamp, is an ideal setting for the construction of shrimp aquaculture ponds, requiring only a modest investment in levee construction and low-head pumping equipment. Proximity of the estuarine distributaries allows these to serve as both source for exchange and make-up water, and as receiving bodies for pond effluent. The high tidal range and seasonal freshwater influx provide exchange and dilution water.

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The estuarine water quality monitoring program that we report on builds upon and expands previous Estero Real estuarine water quality monitoring projects conducted under the auspices of the European Union PRADEPESCA project (1994), MEDEPESCA and later ADPESCA (until 1998), and the Centro de Investigación del Camarón, Universidad Centroamericana (UCA/CIC, 1999). In 1999, UCA/CIC and ADPESCA jointly implemented a limited water quality monitoring project in the Estero Real. The Centro de Investigación de Ecosistemas Acuáticos (CIDEA; formerly the Centro de Investigación del Camarón), Universidad Centroamericana, assumed sole responsibility for the monitoring program during 2000. The 1999 and 2000 programs involved monthly sampling of estuarine water from six stations (four stations in the main channel) in the Estero Real system. Samples collected during the year 2000 UCA program were analyzed for salinity, conductivity, water transparency, settleable solids, dissolved oxygen, BOD, COD, pH, total alkalinity, total hardness, nitrate, nitrite, ammonia and soluble reactive phosphorus. Because of its demonstrated capabilities and extensive experience in estuarine water quality and shrimp aquaculture, the Centro de Investigación de Ecosistemas Acuáticos, Universidad Centroamericana, was selected to implement the Estero Real estuarine water quality monitoring program herein reported on.

This report addresses results of the activities carried out under the Environmental Monitoring Component of the NOSS/USAID Small-Scale Shrimp Producer Technical Assistance Program for Nicaragua, during the latter part of 2000 and 2001.

ESTUARINE WATER QUALITY MONITORING PROGRAM

Sample Stations

Of the fourteen samples stations selected within the Estero Real system for the water quality monitoring program, twelve were located along the main channel of the Estero Real (Table 1, Figures 1). Sample station 12 was located at the bridge that crosses the Estero Real on the road from Chinandega to Guasaule; water quality data from this station will be used in the future to estimate nutrient loading to the Estero Real from river discharge, providing that river flow data is avaiable. One sample station was located in each of the Dos Aguas Grandes and Dos Aguitas estuaries. Data from the estuarine water quality monitoring program conducted by UCA/CIDEA during 2000 was used in selecting sampling stations. Specifically, we were interested in sampling the Estero Real upstream from, through, and downstream from the sag in dissolved oxygen concentrations observed between UCA sample station 3 (Puerto Morazán) and UCA sample station 4 (Cooprocam), as well as upstream and downstream from the extent of the salinity intrusion, and upstream from the last shrimp farm. Additionally, we included the four main channel sample stations used by UCA/CIDEA during 2000 and two samples stations used for the NOAA/NOS 2001 pesticide study.

Sample Collection

Estuarine water samples were collected monthly during January to March 2001 at sample stations 1, 3, 5, and 9 (Table 1). No water samples were collected during April 2001 because the outboard motor of the sample boat failed; a new motor was purchased and collection of water samples resumed in May 2001. Water samples for nutrient analyses were collected bi-weekly from 10 May through 22 November 2001 at all 14 sample stations (Table 2). Water samples for microbiological analyses were collected monthly from June through November 2001 at 6 sample stations within the Estero Real (Table 1 & 2, Figure 1).

Estuarine water samples for nutrient analyses were collected from the center of the estuary at each sample station at high tide using a column sampler (1-2 m long) constructed of 2-inch diameter PVC pipe (Boyd, 1979). The boat position was maintained stationary during sample collection. A five-gallon plastic bucket was used to pool sub-samples at each sampling station. At each site the bucket was rinsed with site water prior to sample collection. Sufficient vertical water column samples were collected with sampler to fill the bucket. A clean, labeled, 2-L sample bottle was used to collect a water sample from the bucket. Each sample bottle was capped tightly, stored on ice in an opaque cooler, and transported to the laboratory for analysis.

Water samples for microbiological analyses were collected simultaneously with water samples for nutrient analyses. At each station, a sterile, labeled, 1-L sample bottle was submerged to 30 cm depth and filled. The full sample bottle was capped tightly, stored on ice in an opaque cooler, and transported to the laboratory for analysis.

Table 1. Description of estuarine water quality monitoring sampling stations, Estero Real, Nicaragua. The numbers in parentheses represent shared sample stations: XS are depth cross-section stations, UCA are UCA/CIDEA 2000 stations, NOAA are NOAA 2001 pesticide study stations). Water samples from all stations were analyzed for nutrient concentrations. Station 12 is excluded from dissolved oxygen/temperature/salinity profile measurements.

Sampling Station	GPS Coordinates	Description	Analysis
1 (XS37, UCA 1)	12° 55' N, 87 21' W	Estero El Chorro	Nutrients, Microbiological
2 (XS 46, NOAA 014)	12 55' N, 87 18' W	Estero Dos Aguas Grandes	Nutrients
3 (XS17, UCA 2)	12 53' N, 87 16' W	Camilo Ortega	Nutrients, Microbiological
4 (XS 20, NOAA 016)	12 54' N, 87 13' W	Estero Dos Aguitas	Nutrients
5 (XS 31, UCA 3)	12 51' N, 87 10' W	Puerto Morazán	Nutrients, Microbiological
6 (XS 10)	12 50' N, 87 07' W	Estero Palomino	Nutrients
7 (XS 9)	12 51' N, 87 07' W	FRIXSA	Nutrients
8 (XS 6)	12 51' N, 87 03' W	Estero Palo Blanco	Nutrients
9 (XS 5, UCA 4)	12 51' N, 87 03' W	COOPROCAM	Nutrients, Microbiological
10 (XS 2)	12 50' N, 86 59' W	Llano Verde	Nutrients
11 (XS 1)	12 50' N, 86 59' W	La Polvosa	Nutrients
12 (XS 34)	12 48' N, 86 55' W	Estero Real Bridge	Nutrients
13 (XS 23)	12 56' N, 87 11' W	Estero Dos Aguitas (Los Perejiles)	Nutrients, Microbiological
14 (XS 50)	12 57' N, 87 15' W	Estero Dos Aguas Grandes (Torrecillas)	Nutrients, Microbiological

Sample Analysis

The water quality laboratory at the UCA/CIDEA was up-graded as part of this project during May-June, and laboratory equipment and supplies were augmented (Figure 2). The laboratory equipment and supplies arrived in country in May 2001(see Appendix I). Nutrient analyses were performed on water samples from all sampling stations. Total alkalinity, total hardness, soluble reactive phosphorus, total suspended solids, sulfates, total ammonia nitrogen, nitrite, nitrate, 5-day biochemical oxygen demand (BOD_5), chlorophyll *a*, and settleable solids were determined according to methods given in Standard Methods (APHA, 1998). Total nitrogen and total phosphorus were analyzed according to the methodology of Grasshoff et al. (1983). Reactive silicate was determined according to the procedure given in Strickland and Parsons (1977).

Table 2. Schedule for collection of estuarine water samples for nutrient and microbiological analyses, and for *in situ* measurement of dissolved oxygen/temperature/salinity (DO/T/Sal) profiles in the Estero Real, Nicaragua.

Date	Nutrient Analyses	Microbiological Analyses	DO/T/Sal Profiles
16 January 2001	X		
13 February 2001	X		
26 – 27 March 2001	X		
15 – 16 May 2001	X		
24 – 25 May 2001	X	X	X
7 – 8 June 2001	X		
25 – 26 June 2001	X	X	X
9 – 10 July 2001	X		
23 – 24 July 2001	X	X	X
7 – 8 August 2001	X		
22 – 23 August 2001	X	X	X
5 – 6 September 2001	X		
19 – 20 September 2001	X	X	X
3 – 4 October 2001	X		
17 – 18 October 2001	X	X	X
7 – 8 November 2001	X		
21 – 22 November 2001	X	X	X

Fewer variables were analyzed during the period January – May 2001 (no samples were collected during April because the boat motor was out of service). During January – May water samples were analyzed for total alkalinity, total hardness, soluble reactive phosphorus, nitrite, nitrate, total ammonia nitrogen, BOD_5, and chlorophyll *a*. Beginning in June 2001 the suite of nutrient analyses was expanded to include total suspended solids, sulfate, and settleable solids. In July, total nitrogen and total phosphorus analyses were initiated because the necessary reagents finally had arrived in country.

The following microbiological analyses were conducted on water samples: total coliforms, fecal coliforms, *Vibrio* spp., *Vibrio cholerae*, and salmonella. Analytical procedures were according to Standard Methods (APHA, 1998).

Figure 1. Locations of water quality (nutrient) and microbiological sampling stations in the Estero Real system, Nicaragua, during the estuarine water quality monitoring program implemented from January through November 2001.

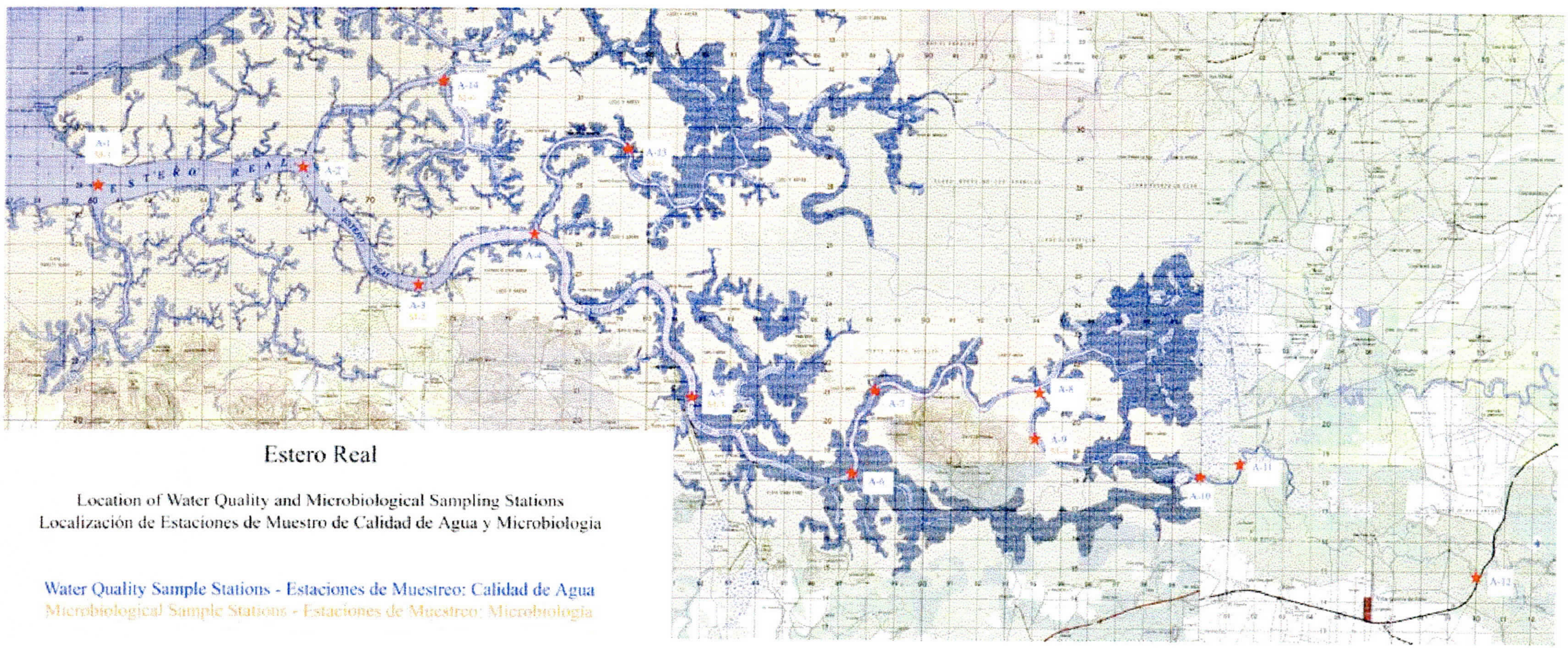

Figure 2. Water quality laboratory at the Centro de Investigación de Ecosistemas Acuáticos, Universidad Centroamericano.

Results and Discussion

The estuarine water quality monitoring program was initiated in January 2001, expanded in terms of variables analyzed in June and July, and continued through November as part of this project. In fact, collection of water samples continued into December, and the UCA/CIDEA plans to continue the estuarine water quality monitoring program during 2002. However, only data through November 2001 are reported herein. Continued monitoring of water quality in the Estero Real, however, depends upon the UCA/CIDEA securing the necessary financial support.

The network of sample stations covers the main channel of the Estero Real almost in its entirety, and samples two of its principal tributaries approximately 6 km upstream from their confluence with the main channel. In order to sample additional stations in these and other tributaries in the future, a larger, faster boat must be procured.

Results of nutrient analyses of water samples are presented in tabular and graphical form (Tables 3-19, Figures 3-19). Results of microbiological analyses are presented in Table 20. The expanded set of sample analyses and sample sites were implemented only from June through November. Because the sampling conducted as part of this program is the start of a long-term sampling program, it is too soon to analyze the data. At least two complete years of data are necessary to establish a baseline of data. A two-year data set will provide information on seasonal and annual variation.

Dissolved oxygen (DO) concentration at 0.5 m depth was high (5-7 mg/L) near the mouth of the Estero Real (El Chorro sample station), and declined with distance upstream. There was a DO sag, i.e., DO concentrations < 1 mg/L, generally observed from the FRIXSA to the La Polvosa sample stations. At the Puente Real sample station, DO concentration generally was recovering and ranged from 1-4 mg/L. While there is no single value of DO that demarcates acceptable from unacceptable water quality, as a general rule concentrations in excess of 5 mg/L assure maintenance of almost all aerobic species, and only the most resilient can survive with DO's below 2 mg/L for long periods of time. Occurrence of DO's below 1 mg/L for any substantial period of time will eliminate most higher aerobic forms.

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No trends were observed for any of the other water quality variables analyzed during this project.

Table 3. Results of 16 January 2001 water quality analyses from sample stations in the Estero Real system. Samples were collected at depths of 0.5 m and just off the estuary bottom.

Sample Station	Depth (m)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Total Alkalinity (mg/L)
1 - El Chorro	0.50	26.8	30.7	5.11	0.10	7.08	45.0	87.33
1 - El Chorro	8.00	27.0	30.6	4.97	0.30	7.14		97.00
3 - Camilo Ortega	0.50	28.0	28.9	3.25	0.10	7.09	25.0	66.67
3 - Camilo Ortega	8.00	27.4	29.4	3.34	0.10	7.09		84.00
5 - Puerto Morazán	0.50	28.6	22.4	1.87	0.60	7.86	15.0	142.00
5 - Puerto Morazán	7.00	28.4	23.1	1.84	1.00	7.89		97.33
9 - Cooprocam	0.50	29.3	12.2	0.69	2.50	7.87	5.0	127.33
9 - Cooprocam	4.00	29.1	11.7	0.21	1.75	7.91		130.67
13 - Los Perejiles	0.50	26.4	23.2	1.67	1.20	7.02	10.0	139.33
13 - Los Perejiles	4.00	26.2	23.5	1.59	17.00	7.01		152.67
14 - Torrecillas	0.50	30.1	27.5	3.23	0.40	7.40	15.0	150.67
14 - Torrecillas	6.00	29.4	28.6	3.27	0.40	7.12		177.33

Sample Station	Depth (m)	PO_4-P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Sulfate (mg/L)	Total Hardness (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.047	0.233	0.008	0.169	151.67	6,936	15
1 - El Chorro	8.00	0.043	0.240	0.005	0.149	159.21	6,528	12
3 - Camilo Ortega	0.50	0.079	0.343	0.007	0.027	164.90	8,211	7
3 - Camilo Ortega	8.00	0.086	0.378	0.008	0.142	199.31	6,732	7
5 - Puerto Morazán	0.50	0.157	0.549	0.005	0.057	182.55	6,222	5
5 - Puerto Morazán	7.00	0.023	0.546	0.005	0.306	205.59	5,508	7
9 - Cooprocam	0.50	0.329	0.354	0.003	0.362	135.20	3,060	5
9 - Cooprocam	4.00	0.342	0.652	0.003	0.956	170.59	3,825	6
13 - Los Perejiles	0.50	0.108	0.456	0.006	0.051	116.37	6,426	80
13 - Los Perejiles	4.00	0.119	0.455	0.004	0.083	160.88	5,661	10
14 - Torrecillas	0.50	0.090	0.341	0.004	0.159	106.57	6,375	54
14 - Torrecillas	6.00	0.077	0.353	0.004	0.037	169.41	6,732	12

Table 4. Results of 13 February 2001 water quality analyses from sample stations in the Estero Real system. Samples were collected at depths of 0.5 m and just off the estuary bottom.

Sample Station	Depth (m)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Total Alkalinity (mg/L)
1 - El Chorro	0.50	27.5	32.1	3.24	0.30	7.71	10.0	137.33
1 - El Chorro	8.00	26.6	31.8	2.99	0.70	7.67		145.00
3 - Camilo Ortega	0.50	27.6	31.9	3.79	0.20	7.60	15.0	166.00
3 - Camilo Ortega	8.00	27.3	30.5	3.08	0.30	7.63		177.00
5 - Puerto Morazán	0.50	27.2	28.1	3.46	0.10	7.53	20.0	214.00
5 - Puerto Morazán	7.00	27.8	28.0	2.46	0.20	7.61		214.00
9 - Cooprocam	0.50	28.2	18.4	1.37	0.40	7.59	5.0	290.00
9 - Cooprocam	4.00	28.0	18.8	1.52	3.00	7.60		132.67
13 - Los Perejiles	0.50	27.4	27.6	3.60	0.40	7.55	5.0	26.67
13 - Los Perejiles	4.00	26.5	28.5	3.55	0.70	7.56		28.67
14 - Torrecillas	0.50	27.2	32.3	3.68	0.20	7.38	25.0	27.33
14 - Torrecillas	6.00	26.8	33.0	2.42	0.60	7.49		26.00

Sample Station	Depth (m)	PO_4-P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Sulfate (mg/L)	Total Harndess (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.047	0.095	0.008	0.014	202.06	8,772	122
1 - El Chorro	8.00	0.043	0.098	0.006	0.018	163.33	11,832	64
3 - Camilo Ortega	0.50	0.079	0.103	0.015	0.055	154.41	13,872	120
3 - Camilo Ortega	8.00	0.086	0.101	0.013	0.057	87.65	11,220	121
5 - Puerto Morazán	0.50	0.157	0.263	0.004	0.057	185.78	13,464	136
5 - Puerto Morazán	7.00	0.167	0.381	0.005	0.022	169.31	10,200	172
9 - Cooprocam	0.50	0.329	0.663	0.005	0.010	219.02	11,934	129
9 - Cooprocam	4.00	0.342	0.563	0.005	0.010	145.69	10,506	143
13 - Los Perejiles	0.50	0.108	0.169	0.003	0.126	126.67	14,892	50
13 - Los Perejiles	4.00	0.119	0.279	0.003	0.012	116.77	8,772	98
14 - Torrecillas	0.50	0.096	0.135	0.014	0.076	156.57	14,484	126
14 - Torrecillas	6.00	0.077	0.143	0.019	0.026	112.94	12,648	127

Table 5. Results of 26 March 2001 water quality analyses from sample stations in the Estero Real system. Samples were collected at depths of 0.5 m.

Sample Station	Depth (m)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Total Alkalinity (mg/L)
1 - El Chorro	0.50	27.5	32.0	5.12	0.10	7.62	6.0	176.00
3 - Camilo Ortega	0.50	27.9	31.8	4.15	0.20	7.46	18.0	210.00
5 - Puerto Morazán	0.50	29.3	27.7	3.72	0.60	7.36	7.0	222.00
9 - Cooprocam	0.50	27.0	18.6	1.14	0.20	7.42		386.00

Sample Station	Depth (m)	PO_4-P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Sulfate (mg/L)	Total Hardness (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.078	0.075	0.018	0.409	223.73	8,058	220
3 - Camilo Ortega	0.50	0.099	0.205	0.016	0.405	195.47	7,650	16
5 - Puerto Morazán	0.50	0.282	0.321	0.005	0.057	221.12	7,242	257
9 - Cooprocam	0.50	0.267	0.366	0.010	0.505	42.53	5,406	205

Table 6. Results of 15 May 2001 water quality analyses from sample stations in the Estero Real system. Samples were collected at depths of 0.5 m.

Sample Station	Depth (m)	Temperature (ºC)	Salinity (g/L)	Dissolve Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Total Alkalinity (mg/L)
1 - El Chorro	0.50	31.9	34.6	7.09	0.00	7.96	70.0	146.60
2 - Dos Aguas Grandes	0.50	31.8	37.2	4.32	0.00	7.98	60.0	190.60
3 - Camilo Ortega	0.50	32.4	31.8	3.97	0.00	7.97	55.0	194.00
4 - Dos Aguitas	0.50	32.1	30.6	3.45	0.00	7.93	40.0	193.20
5 - Puerto.Morazán	0.50	32.0	22.3	3.46	0.00	7.88	35.0	212.00
7 - FRIXSA	0.50	32.6	19.8	2.74	0.01	7.82	15.0	291.20
8 - Palo Blanco	0.50	32.3	17.8	0.29	0.60	7.90	5.0	316.20
9 - Cooprocam	0.50	32.1	16.9	1.90	0.80	7.84	3.0	354.00

Sample Station	Depth (m)	PO_4-P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Sulfate (mg/L)	Total Hardness (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.052	0.020	0.008	0.513	267.10	8,364	180
2 - Dos Aguas Grandes	0.50	0.101	0.182	0.008	0.624	231.77	8,364	225
3 - Camilo Ortega	0.50	0.132	0.208	0.010	0.529	260.36	9,486	241
4 - Dos Aguitas	0.50	0.169	0.258	0.005	0.556	210.25	9,384	227
5 - Puerto.Morazán	0.50	0.337	0.484	0.007	0.060	207.10	7,956	150
7 - FRIXSA	0.50	0.878	0.549	0.007	0.423	200.79	6,426	264
8 - Palo Blanco	0.50	0.658	0.532	0.010	0.432	201.45	5,610	272
9 - Cooprocam	0.50	0.684	0.575	0.010	0.763	210.79	4,794	126

Table 7. Results of 24 May 2001 water quality analyses from sample stations in the Estero Real system. Samples were collected at depths of 0.5 m.

Sample Station	Depth (m)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Total Alkalinity (mg/L)
1 - El Chorro	0.50	30.7	34.7	4.30	0.00	8.30	60	146.00
2 - Dos Aguas Grandes	0.50	30.9	36.0	3.50	0.40	7.99	12.5	146.60
3 - Camilo Ortega	0.50	30.8	35.1	3.13	0.50	8.00	12.5	180.60
4 - Dos Aguitas	0.50	30.7	33.9	3.26	0.30	7.95	10.0	206.00
5 - Puerto .Morazán	0.50	30.9	24.9	2.41	0.90	8.06	7.0	235.20
7 - FRIXSA	0.50	30.0	16.5	1.34	0.50	7.92	4	225.20
8 - Palo Blanco	0.50	29.0	9.0	2.22	9.50	8.30	3.0	328.00
9 - Cooprocam	0.50	27.1	11.8	0.71	1.50	8.00	5.0	318.60
10 - Llano Verde	0.50	27.5	0.0	0.32	1.20	8.10	5.0	382.00
11 - La Polvosa	0.50	28.8	2.0	0.71	0.50	8.24	5.0	336.00
12 - Puente Real	0.50	29.7	0.6	2.80	0.10	7.95	8.0	330.00
13 - Los Perejiles	0.50	30.9	35.3	2.59	0.40	7.90	10.0	189.20
14 - Torrecillas	0.50	30.8	35.6	3.49	0.10	8.16	10.0	144.00

Sample Station	Depth (m)	PO_4-P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Sulfate (mg/L)	Total Hardness (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.043	0.270	0.011	0.019	114.71	6,834	132
2 - Dos Aguas Grandes	0.50	0.031	0.234	0.044	0.038	187.10	7,650	72
3 - Camilo Ortega	0.50	0.160	0.457	0.013	0.030	73.62	6,936	167
4 - Dos Aguitas	0.50	0.156	0.523	0.008	0.085	80.90	7,548	6
5 - Puerto .Morazán	0.50	0.210	0.660	0.006	0.057	28.51	5,712	183
7 - FRIXSA	0.50	0.672	0.521	0.002	0.210	130.79	4,641	183
8 - Palo Blanco	0.50	0.705	0.526	0.109	0.382	154.05	2,097	88
9 - Cooprocam	0.50	0.919	0.578	0.003	0.264	186.01	3,060	94
10 - Llano Verde	0.50	1.017	0.481	0.007	0.289	16.01	1,887	372
11 - La Polvosa	0.50	1.445	0.450	0.005	0.261	7.97	1,632	205
12 - Puente Real	0.50	0.087	0.198	0.008	0.155	91.34	1,479	28
13 - Los Perejiles	0.50	0.058	0.611	0.047	0.083	51.66	6,936	33
14 - Torrecillas	0.50	0.101	0.264	0.007	0.072	127.42	6,834	116

Table 8. Results of 7 June 2001 water quality analyses from sample stations in the Estero Real system. Samples were collected at depths of 0.5 m.

Sample Station	Depth (m)	Temperature (°C)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Total Alkalinity (mg/L)
1 - El Chorro	0.50	30.4	32.4	5.30	0.00	8.12	75.0	248.0
2 - Dos Aguas Grandes	0.50	29.5	32.8	5.53	0.00	8.09	55.0	182.2
3 - Camilo Ortega	0.50	30.8	30.4	4.43	0.00	8.03	45.0	149.2
4 - Dos Aguitas	0.50	30.8	26.6	3.68	0.01	7.98	45.0	-
5 - Puerto .Morazán	0.50	29.5	3.0	1.71	0.03	7.91	12.5	250.0
7 - FRIXSA	0.50	29.7	4.5	0.87	0.03	7.88	7.0	-
8 - Palo Blanco	0.50	29.4	2.8	0.07	1.00	7.96	3.0	-
9 - Cooprocam	0.50	29.5	3.1	0.46	0.20	8.01	7.0	286.0
10 - Llano Verde	0.50	29.7	1.0	0.84	0.01	7.99	7.0	-
11 - La Polvosa	0.50	28.4	0.7	1.88	0.01	8.28	7.0	-
12 - Puente Real	0.50	28.0	0.0	0.61	0.10	7.76	6.0	-
13 - Los Perejiles	0.50	29.7	2.4	1.42	0.20	7.83	8.0	138.0
14 - Torrecillas	0.50	30.0	29.5	3.15	0.01	7.97	22.5	150.6

Sample Station	Depth (m)	PO_4-P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Sulfate (mg/L)	Total Hardness (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.084	0.271	0.011	0.708	124.16	6,732	21
2 - Dos Aguas Grandes	0.50	0.117	0.378	0.018	0.534	-	-	17
3 - Camilo Ortega	0.50	0.165	0.427	0.009	0.533	170.25	6,477	15
4 - Dos Aguitas	0.50	0.208	0.420	0.008	0.511	-	-	11
5 - Puerto .Morazán	0.50	0.409	0.370	0.006	0.057	103.95	3,978	15
7 - FRIXSA	0.50	0.493	0.334	0.009	0.675	-	-	11
8 - Palo Blanco	0.50	0.559	0.361	0.010	0.814	-	-	3
9 - Cooprocam	0.50	0.565	0.334	0.010	0.286	91.34	1,428	29
10 - Llano Verde	0.50	0.553	0.401	0.016	0.159	-	-	82
11 - La Polvosa	0.50	0.520	0.387	0.023	0.364	-	-	496
12 - Puente Real	0.50	0.193	0.002	0.011	0.058	-	-	172
13 - Los Perejiles	0.50	0.171	0.035	0.015	0.354	108.40	1,326	80
14 - Torrecillas	0.50	0.181	0.465	0.019	0.097	188.84	6,171	8

Table 9. Results of 25 June 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Depth (m)	Temperature (°C)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	0.50	29.6	31.6	4.80	<0.5	8.23	40.0	3.535
2 - Dos Aguas Grandes	0.50	29.5	31.5	4.60	<0.5	8.18	24.0	4.290
3 - Camilo Ortega	0.50	29.4	30.4	3.72	<0.5	8.15	23.0	4.747
4 - Dos Aguitas	0.50	29.4	29.2	3.37	0.6	8.05	25.0	5.051
5 - Puerto .Morazán	0.50	29.7	19.2	3.23	28.0	8.00	10.0	8.976
6 - Estero Palomino	0.50	29.4	8.0	4.66	210.0	8.07	3.0	4.354
7 - FRIXSA	0.50	30.2	10.0	1.09	45.0	8.03	3.0	4.229
8 - Palo Blanco	0.50	31.2	8.0	2.11	120.0	8.04	2.0	5.051
9 - Cooprocam	0.50	30.3	6.4	0.74	81.0	8.05	2.0	5.398
10 - Llano Verde	0.50	31.3	1.6	0.87	<0.5	8.27	2.0	5.854
11 - La Polvosa	0.50	30.3	2.3	0.76	1.0	8.26	3.0	5.921
12 - Puente Real	0.50	29.9	0.2	3.55	13.0	8.38	4.0	5.950
13 - Los Perejiles	0.50	29.2	20.1	2.35	20.0	7.83	7.5	1.780
14 - Torrecillas	0.50	29.4	30.4	3.72	<0.5	8.22	8.0	0.582

Sample Station	Depth (m)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N(mg/L)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.002	0.008	0.181	0.008	0.048	0.29	224
2 - Dos Aguas Grandes	0.50	0.004	0.387	0.416	0.002	0.082	0.26	227
3 - Camilo Ortega	0.50	0.006	0.390	0.279	0.002	0.138	0.28	242
4 - Dos Aguitas	0.50	0.008	0.390	0.416	0.002	0.106	1.12	225
5 - Puerto .Morazán	0.50	0.019	0.390	0.416	0.005	0.216	1.88	229
6 - Estero Palomino	0.50	0.053	0.067	0.102	0.013	0.422	3.19	10
7 - FRIXSA	0.50	0.080	-	-	0.016	0.397	3.70	201
8 - Palo Blanco	0.50	0.039	0.232	0.264	0.005	0.414	9.63	221
9 - Cooprocam	0.50	0.046	0.012	0.014	0.007	0.252	6.80	216
10 - Llano Verde	0.50	0.049	0.010	0.000	0.033	0.278	5.12	234
11 - La Polvosa	0.50	0.051	0.089	0.110	0.031	0.001	1.86	217
12 - Puente Real	0.50	-	0.040	0.048	0.002	-	0.02	230
13 - Los Perejiles	0.50	0.014	0.232	0.251	0.005	0.202	1.11	221
14 - Torrecillas	0.50	0.005	0.082	0.087	0.011	0.047	0.63	224

Table 10. Results of 10 July 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Depth (m)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	0.50	30.1	22.3	5.19	<0.5	8.19	37.0	2.628
2 - Dos Aguas Grandes	0.50	30.6	31.1	3.11	0.0	8.11	53.0	2.737
3 - Camilo Ortega	0.50	30.4	30.0	3.61	0.0	8.09	35.0	2.281
4 - Dos Aguitas	0.50	30.2	28.3	3.26	<0.5	8.01	20.0	2.431
5 - Puerto .Morazán	0.50	30.5	19.9	2.38	<0.5	8.09	22.0	0.080
6 - Estero Palomino	0.50	30.4	15.5	1.76	0.0	8.06	15.0	0.779
7 - FRIXSA	0.50	30.5	15.2	1.70	<0.5	8.07	12.0	1.078
8 - Palo Blanco	0.50	30.2	11.5	1.86	<0.5	8.02	5.0	0.758
9 - Cooprocam	0.50	30.6	12.1	1.03	<0.5	8.03	14.0	1.163
10 - Llano Verde	0.50	30.0	8.0	2.05	0.2	8.12	7.0	0.035
11 - La Polvosa	0.50	29.9	4.9	2.51	<0.5	8.13	4.0	0.816
12 - Puente Real	0.50	29.2	0.4	3.58	0.3	8.22	10.0	0.088
13 - Los Perejiles	0.50	30.0	22.4	2.76	0.0	7.99	15.0	2.356
14 - Torrecillas	0.50	30.9	30.5	3.63	<0.5	8.18	55.0	2.548

Sample Station	Depth (m)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N(mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.50	0.005	0.100	0.117	0.096	0.041	213
2 - Dos Aguas Grandes	0.50	0.004	0.155	0.154	0.073	0.067	209
3 - Camilo Ortega	0.50	0.005	0.182	0.142	0.078	0.059	104
4 - Dos Aguitas	0.50	0.011	0.292	0.051	0.196	0.194	214
5 - Puerto .Morazán	0.50	0.011	0.252	0.061	0.113	0.191	217
6 - Estero Palomino	0.50	0.015	0.249	0.030	0.223	0.194	215
7 - FRIXSA	0.50	0.000	0.187	0.000	0.053	0.146	212
8 - Palo Blanco	0.50	0.015	0.136	0.033	0.502	0.193	204
9 - Cooprocam	0.50	0.029	0.117	0.013	0.146	0.183	207
10 - Llano Verde	0.50	0.015	0.190	0.070	0.369	0.179	210
11 - La Polvosa	0.50	0.024	0.179	0.012	0.509	0.183	208
12 - Puente Real	0.50	0.030	0.289	0.019	0.112	0.202	218
13 - Los Perejiles	0.50	0.014	0.061	0.033	0.249	0.291	208
14 - Torrecillas	0.50	0.005	0.122	0.069	0.103	0.198	219

Table 11. Results of 27 July 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Total Alkalinity (mg/L)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	108.0	31.6	32.5	5.28	0.0	7.85	55.0	2.628
2 - Dos Aguas Grandes	292.0	31.0	31.8	3.56	0.0	7.81	25.0	2.737
3 - Camilo Ortega	184.0	31.5	31.1	3.32	< 0.5	7.79	35.0	2.281
4 - Dos Aguitas	414.0	31.5	28.9	1.90	<0.5	7.67	12.0	2.431
5 - Puerto .Morazán	236.0	31.9	22.1	2.37	1.0	7.83	25.0	0.080
6 - Estero Palomino	358.0	29.9	7.0	4.25	3.5	7.73	10.0	0.779
7 - FRIXSA	320.0	31.6	12.8	0.79	8.2	7.77	8.0	1.078
8 - Palo Blanco	388.0	33.9	10.4	1.91	4.5	7.76	3.0	0.758
9 - Cooprocam	420.0	31.4	7.6	0.97	8.5	7.47	5.0	1.163
10 - Llano Verde	402.0	30.5	2.5	0.75	4.0	8.02	3.0	0.035
11 - La Polvosa	212.0	29.9	1.4	1.32	<0.5	7.83	3.0	0.816
12 - Puente Real	130.0	28.9	0.5	3.12	0.0	7.98	10.0	0.088
13 - Los Perejiles	232.0	30.9	28.5	1.54	1.0	7.60	5.0	2.356
14 - Torrecillas	318.0	31.1	30.7	2.78	0.0	7.77	45.0	2.548

Sample Station	Total Hardness (mg/L)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	9,690	0.000	0.188	0.006	0.243	0.160	0.26	213
2 - Dos Aguas Grandes	6,732	0.001	0.263	0.008	0.235	0.284	0.64	209
3 - Camilo Ortega	7,038	0.001	0.310	0.007	0.177	0.175	0.58	104
4 - Dos Aguitas	6,018	0.003	0.397	0.008	0.305	0.200	0.82	214
5 - Puerto .Morazán	5,100	0.008	0.336	0.009	0.294	0.226	0.58	217
6 - Estero Palomino	7,242	0.012	0.266	0.006	0.674	0.094	5.96	215
7 - FRIXSA	7,650	0.012	0.844	0.007	0.277	0.236	5.84	212
8 - Palo Blanco	4,488	0.015	0.235	0.005	2.693	0.231	11.74	204
9 - Cooprocam	4,998	0.016	0.197	0.007	2.698	0.444	3.86	207
10 - Llano Verde	4,896	0.018	0.278	0.006	0.286	0.225	5.94	210
11 - La Polvosa	7,038	0.017	0.429	0.009	0.296	0.210	0.26	208
12 - Puente Real	13,362	0.009	0.015	0.000	0.682	0.202	0.12	218
13 - Los Perejiles	7,446	0.006	0.496	0.007	0.285	0.000	1.68	208
14 - Torrecillas	7,854	0.004	0.381	0.005	0.260	0.360	0.44	219

Table 12. Results of 7 August 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	31.3	31.7	4.65	0.00	7.46	48.0	0.475
2 - Dos Aguas Grandes	31.4	31.0	4.12	0.00	7.63	40.0	0.792
3 - Camilo Ortega	31.4	29.9	4.42	0.00	7.62	50.0	1.716
4 - Dos Aguitas	31.3	28.6	4.02	0.00	7.61	45.0	2.858
5 - Puerto .Morazán	31.9	16.7	2.83	0.00	7.74	15.0	3.957
6 - Estero Palomino	29.9	2.7	4.31	2.60	7.74	3.0	6.537
7 - FRIXSA	31.9	9.7	1.31	4.00	7.73	5.0	5.582
8 - Palo Blanco	32.7	5.1	0.99	0.50	7.72	2.0	6.729
9 - Cooprocam	31.6	3.0	0.97	0.30	7.75	5.0	7.012
10 - Llano Verde	30.6	0.7	2.75	1.10	7.73	3.0	7.121
11 - La Polvosa	30.6	0.4	3.41	1.30	7.72	3.0	7.084
12 - Puente Real	28.9	0.4	3.29	0.00	7.78	-	6.425
13 - Los Perejiles	30.7	27.7	1.91	0.00	7.56	40.0	1.169
14 - Torrecillas	31.2	30.4	3.10	0.00	7.51	40.0	0.096

Sample Station	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.002	0.121	0.006	0.430	0.196	1
2 - Dos Aguas Grandes	0.003	0.171	0.005	0.557	0.181	225
3 - Camilo Ortega	0.003	0.197	0.005	0.353	0.183	100
4 - Dos Aguitas	0.004	0.206	0.005	0.368	0.228	278
5 - Puerto .Morazán	0.009	0.311	0.005	0.032	0.378	225
6 - Estero Palomino	0.009	0.840	0.005	0.159	0.447	220
7 - FRIXSA	0.013	0.190	0.005	0.003	0.220	194
8 - Palo Blanco	0.012	0.158	0.005	0.271	0.169	208
9 - Cooprocam	0.012	0.196	0.005	0.476	0.210	205
10 - Llano Verde	0.009	0.221	0.009	0.905	0.231	205
11 - La Polvosa	0.012	0.420	0.007	0.517	0.253	185
12 - Puente Real	0.002	0.184	0.000	1.546	-	122
13 - Los Perejiles	0.005	0.200	0.009	0.852	0.259	225
14 - Torrecillas	0.003	0.168	0.011	0.888	0.224	171

Table 13. Results of 22 August 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Total Alkalinity (mg/L)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	109.20	30.9	33.4	2.29	0.3	7.60	55.0	1.529
2 - Dos Aguas Grandes	102.00	30.8	32.8	2.88	1.0	7.60	10.0	2.129
3 - Camilo Ortega	132.00	30.7	31.8	2.51	0.4	7.48		3.060
4 - Dos Aguitas	132.00	30.9	30.2	2.40	0.4	7.55	7.0	3.655
5 - Puerto .Morazán	178.60	31.2	24.1	1.39	0.5	7.54	10.0	8.074
6 - Estero Palomino	146.00	30.8	19.8	3.27	1.0	7.54	5.0	8.837
7 - FRIXSA	263.20	31.3	18.0	1.05	4.0	7.53	3.0	10.232
8 - Palo Blanco	220.00	34.9	15.8	2.69	15.0	7.60	2.0	9.832
9 - Cooprocam	178.60	32.1	9.1	0.47	15.0	7.56	3.0	10.232
10 - Llano Verde	149.20	31.3	1.8	0.62	30.0	7.73	2.0	10.232
11 - La Polvosa	198.00	31.4	1.0	1.40	22.0	7.71	2.0	10.232
12 - Puente Real	257.20	29.2	0.4	2.04	0.0	7.54	3.0	7.127
13 - Los Perejiles	150.00	29.9	28.1	2.10	0.5	7.45	5.0	9.613
14 - Torrecillas	111.20	30.4	32.9	3.29	0.4	7.52	7.0	3.314

Sample Station	Total Hardness (mg/L)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	4,080	0.001	0.186	0.005	0.108	0.115	1.12	1
2 - Dos Aguas Grandes	4,488	0.002	0.275	0.007	0.225	0.160	1.68	212
3 - Camilo Ortega	5,304	0.003	0.346	0.005	0.161	0.284	1.24	205
4 - Dos Aguitas	5,202	0.037	0.349	0.006	0.184	0.175	1.36	175
5 - Puerto .Morazán	4,488	0.007	0.468	0.007	0..474	0.200	1.32	26
6 - Estero Palomino	6,120	0.008	0.356	0.008	0.476	0.226	2.32	208
7 - FRIXSA	4,284	0.011	0.402	0.008	0.671	0.202	4.76	214
8 - Palo Blanco	4,590	0.012	0.399	0.008	1.260	0.236	19.28	177
9 - Cooprocam	4,692	0.011	0.434	0.005	1.257	0.231	18.48	96
10 - Llano Verde	2,754	0.007	0.529	0.010	1.256	0.444	31.52	224
11 - La Polvosa	3,774	0.008	0.555	0.006	2.306	0.225	26.68	217
12 - Puente Real	3,162	0.002	0.679	0.005	0.196	0.094	0.12	223
13 - Los Perejiles	4,284	0.003	0.485	0.006	0.068	0.360	1.68	190
14 - Torrecillas	4,896	0.005	0.282	0.007	0.023	0.210	1.40	207

Table 14. Results of 5 September 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Temperature (°C)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	30.8	30.2	4.55	< 0.5	7.65	15.0	2.516
2 - Dos Aguas Grandes	31.2	29.4	3.79	0.0	7.63	40.0	3.482
3 - Camilo Ortega	31.1	26.8	3.21	0.0	7.75	30.0	2.831
4 - Dos Aguitas	31.2	22.9	3.21	< 0.5	7.78	20.0	6.251
5 - Puerto .Morazán	30.1	11.9	2.35	< 0.5	7.88	20.0	9.376
6 - Estero Palomino	27.6	4.6	3.64	0.5	7.93	2.0	8.944
7 - FRIXSA	30.5	6.8	1.82	2.5	7.83	2.0	6.403
8 - Palo Blanco	33.1	5.5	2.19	0.0	7.84	7.0	6.246
9 - Cooprocam	30.8	2.5	0.70	0.5	7.87	1.0	2.417
10 - Llano Verde	30.4	0.7	3.90	0.5	7.74	3.0	9.064
11 - La Polvosa	30.5	0.3	4.34	0.8	7.66	2.0	10.336
12 - Puente Real	28.7	0.4	2.43	0.0	8.05	5.0	10.336
13 - Los Perejiles	26.3	15.7	5.16	0.0	7.77	45.0	4.867
14 - Torrecillas	29.1	26.0	1.42	0.0	7.60	20.0	3.719

Sample Station	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.004	0.000	0.007	0.017	-	-
2 - Dos Aguas Grandes	0.001	0.002	0.007	0.026	-	-
3 - Camilo Ortega	0.001	0.001	0.008	0.027	-	-
4 - Dos Aguitas	0.011	0.007	0.012	0.012	-	-
5 - Puerto .Morazán	0.014	0.003	0.010	0.017	-	-
6 - Estero Palomino	0.011	0.012	0.021	0.021	-	-
7 - FRIXSA	0.012	0.006	0.021	0.075	-	-
8 - Palo Blanco	0.008	0.013	0.013	0.017	-	-
9 - Cooprocam	0.010	0.007	0.025	0.030	-	-
10 - Llano Verde	0.010	0.010	0.030	0.051	-	-
11 - La Polvosa	0.009	0.002	0.024	0.069	-	-
12 - Puente Real	0.000	0.057	0.006	0.175	-	-
13 - Los Perejiles	0.001	0.033	0.015	0.132	-	-
14 - Torrecillas	0.007	0.036	0.009	0.123	-	-

Table 15. Results of 19 September 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Total Alkalinity (mg/L)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	116.60	28.8	29.9	5.28	1.2	7.99	8.0	0.635
2 - Dos Aguas Grandes	161.20	30.2	29.8	3.56	4.0	7.81	5.0	2.948
3 - Camilo Ortega	153.20	30.1	27.2	3.32	1.1	7.77	5.0	3.818
4 - Dos Aguitas	166.00	30.2	21.2	1..90	4.5	7.75	4.0	4.712
5 - Puerto .Morazán	184.00	29.1	0.4	2.37	9.1	7.85	5.0	8.084
6 - Estero Palomino	194.00	28.1	5.7	4.25	6.5	7.99	3.0	8.084
7 - FRIXSA	165.20	29.4	7.8	0.79	20.0	7.77	3.0	8.084
8 - Palo Blanco	149.20	32.1	6.3	1.91	16.0	7.83	2.0	8.084
9 - Cooprocam	150.00	29.8	4.2	0.97	4.0	8.07	2.0	8.084
10 - Llano Verde	176.00	29.4	0.9	0.75	2.2	7.75	3.0	8.084
11 - La Polvosa	169.20	29.5	0.3	1.32	1.5	7.79	3.0	8.084
12 - Puente Real	141.20	29.2	0.4	3.12	0.0	8.11	3.0	8.084
13 - Los Perejiles	153.20	27.3	16.8	1.54	3.2	7.85	10.0	8.084
14 - Torrecillas	139.20	28.1	25.1	2.78	0.5	7.91	17.0	8.084

Sample Station	Total Hardness (mg/L)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	2,346	0.011	0.005	0.006	0.002	0.202	1.16	-
2 - Dos Aguas Grandes	1,836	0.013	0.005	0.008	0.004	0.251	1.36	-
3 - Camilo Ortega	1,428	0.010	0.003	0.007	0.025	0.084	1.32	-
4 - Dos Aguitas	1,632	0.016	0.005	0.007	0.004	0.057	2.20	-
5 - Puerto .Morazán	1,020	0.016	0.007	0.009	0.003	0.202	1.08	-
6 - Estero Palomino	408	0.011	0.000	0.013	0.033	0.442	2.36	-
7 - FRIXSA	408	0.036	0.007	0.008	0.041	0.247	1.32	-
8 - Palo Blanco	204	0.021	0.014	0.027	0.032	0.510	1.88	-
9 - Cooprocam	204	0.027	0.000	0.009	0.025	0.248	0.96	-
10 - Llano Verde	204	0.027	0.002	0.008	0.025	0.241	0.96	-
11 - La Polvosa	204	0.025	0.002	0.008	0.029	0.436	0.72	-
12 - Puente Real	306	0.017	0.015	0.006	0.058	0.034	0.08	-
13 - Los Perejiles	816	0.013	0.037	0.007	0.121	0.352	3.20	-
14 - Torrecillas	1,530	0.010	0.035	0.008	0.116	0.211	1.12	-

Table 16. Results of 3 October 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Temperature (°C)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	31.0	19.5	3.9	< 0.5	7.78	72.0	2.887
2 - Dos Aguas Grandes	30.6	18.3	2.8	< 0.5	7.75	55.0	3.031
3 - Camilo Ortega	31.0	9.9	4.9	< 0.5	7.72	25.0	3.770
4 - Dos Aguitas	29.9	9.6	3.2	0.3	7.51	5.0	3.626
5 - Puerto .Morazán	30.7	1.5	2.8	0.2	8.14	5.0	4.496
6 - Estero Palomino	29.8	2.2	3.1	1.5	7.89	3.0	5.520
7 - FRIXSA	30.6	1.0	2.5	1.8	7.75	2.0	3.490
8 - Palo Blanco	31.5	0.7	2.0	10.0	7.57	1.0	3.276
9 - Cooprocam	30.5	0.5	1.8	0.3	7.37	3.0	4.843
10 - Llano Verde	31.4	0.3	3.0	0.3	7.31	4.0	5.267
11 - La Polvosa	31.6	0.2	2.9	0.2	7.40	12.0	8.076
12 - Puente Real	29.3	0.2	3.4	< 0.5	7.75	10.0	2.025
13 - Los Perejiles	30.6	1.9	3.9	0.2	7.33	12.0	7.932
14 - Torrecillas	30.3	18.3	2.4	< 0.5	7.73	57.0	6.430

Sample Station	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.004	0.12	0.010	0.062	0.168	-
2 - Dos Aguas Grandes	0.005	0.12	0.009	0.060	0.142	-
3 - Camilo Ortega	0.005	0.19	0.006	0.048	0.145	-
4 - Dos Aguitas	0.008	0.21	0.008	0.089	0.146	-
5 - Puerto .Morazán	0.013	0.15	0.012	0.201	0.176	-
6 - Estero Palomino	0.015	0.25	0.010	0.236	0.236	-
7 - FRIXSA	0.015	0.13	0.007	0.339	0.371	-
8 - Palo Blanco	0.015	0.10	0.011	1.405	0.296	-
9 - Cooprocam	0.017	0.12	0.009	0.267	0.253	-
10 - Llano Verde	0.012	0.11	0.007	0.124	0.211	-
11 - La Polvosa	0.009	0.08	0.006	0.075	0.201	-
12 - Puente Real	0.008	0.04	0.006	0.084	0.208	-
13 - Los Perejiles	0.007	0.17	0.007	0.176	0.308	-
14 - Torrecillas	0.005	0.20	0.008	0.001	0.208	-

Table 17. Results of 17 October 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Total Alkalinity (mg/L)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	121.0	30.3	25.8	3.72	3.0	7.53	5.0	1.585
2 - Dos Aguas Grandes	133.0	30.4	21.9	2.92	3.5	7.52	5.0	2.636
3 - Camilo Ortega	122.0	30.8	19.6	2.76	4.5	7.62	20.0	2.754
4 - Dos Aguitas	138.5	31.1	16.3	1.78	12.0	7.33	5.0	3.719
5 - Puerto .Morazán	168.5	30.9	7.7	1.27	7.5	7.43	10.0	4.763
6 - Estero Palomino	193.0	29.6	6.5	1.64	15.0	7.40	2.0	5.592
7 - FRIXSA	210.0	30.9	3.5	1.08	34.0	7.45	5.0	5.523
8 - Palo Blanco	216.0	31.1	2.1	2.49	31.0	7.55	2.0	5.299
9 - Cooprocam	250.0	30.8	1.0	0.47	32.0	7.54	2.0	6.153
10 - Llano Verde	225.0	30.1	0.2	5.08	6.5	7.59	2.0	5.806
11 - La Polvosa	163.0	30.5	0.2	5.61	3.0	7.59	2.0	3.722
12 - Puente Real	177.5	30.0	0.2	3.15	< 0.5	7.34	10.0	4.971
13 - Los Perejiles	135.0	30.7	14.1	1.46	1.5	7.41	10.0	1.676
14 - Torrecillas	158.0	29.8	23.2	3.05	1.5	7.14	6.0	3.373

Sample Station	Total Hardness (mg/L)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	4,896	0.002	0.130	0.023	0.060	0.089	1.28	90
2 - Dos Aguas Grandes	3,570	0.002	0.200	0.014	0.031	0.062	1.48	140
3 - Camilo Ortega	3,774	0.003	0.260	0.015	0.019	0.114	1.24	26
4 - Dos Aguitas	4,080	0.005	0.220	0.018	0.006	0.102	2.80	115
5 - Puerto .Morazán	3,264	0.001	0.250	0.021	0.018	0.102	2.00	122
6 - Estero Palomino	3,978	0.001	0.200	0.044	0.103	0.050	3.00	118
7 - FRIXSA	3,774	0.003	0.140	0.039	0.032	0.115	4.08	103
8 - Palo Blanco	3,366	0.000	0.100	0.056	0.223	0.138	3.80	103
9 - Cooprocam	1,938	0.008	0.080	0.060	0.084	0.156	5.52	122
10 - Llano Verde	1,122	0.003	0.170	0.046	0.169	0.144	2.28	115
11 - La Polvosa	612	0.005	0.050	0.127	0.150	0.156	1.56	122
12 - Puente Real	3,774	0.002	0.220	0.023	0.041	0.128	0.40	103
13 - Los Perejiles	4,692	0.001	0.030	0.013	0.027	0.165	1.24	106
14 - Torrecillas	4,080	0.005	0.050	0.012	0.008	0.121	0.88	135

Table 18. Results of 7 November 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Temperature (°C)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	28.3	23.7	6.59	< 0.5	7.68	45.0	0.686
2 - Dos Aguas Grandes	28.7	21.4	5.60	0.0	7.71	70.0	1.628
3 - Camilo Ortega	29.2	16.3	3.35	0.0	7.53	70.0	1.673
4 - Dos Aguitas	29.3	12.5	2.76	< 0.5	7.46	38.0	1.868
5 - Puerto .Morazán	29.5	3.5	1.74	< 0.5	7.52	20.0	2.540
6 - Estero Palomino	29.1	1.3	2.00	< 0.5	7.52	8.0	3.274
7 - FRIXSA	29.0	0.8	1.83	< 0.5	7.50	10.0	3.282
8 - Palo Blanco	27.6	0.3	3.56	< 0.5	7.49	5.0	3.143
9 - Cooprocam	27.3	0.3	3.79	< 0.5	7.49	3.0	3.407
10 - Llano Verde	27.1	0.2	5.25	< 0.5	7.52	8.0	4.128
11 - La Polvosa	27.2	0.1	5.72	< 0.5	7.42	15.0	4.002
12 - Puente Real	28.1	0.1	2.95	< 0.5	7.70	10.0	4.125
13 - Los Perejiles	29.3	2.8	2.23	< 0.5	7.43	20.0	3.162
14 - Torrecillas	29.3	19.1	3.67	< 0.5	7.42	45.0	1.918

Sample Station	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	0.011	0.03	0.028	0.047	0.042	48
2 - Dos Aguas Grandes	0.014	0.03	0.013	0.053	0.068	74
3 - Camilo Ortega	0.015	0.16	0.015	0.046	0.088	58
4 - Dos Aguitas	0.012	0.26	0.026	0.030	0.096	58
5 - Puerto .Morazán	0.016	0.25	0.021	0.002	0.117	67
6 - Estero Palomino	0.018	0.15	0.048	0.050	0.456	68
7 - FRIXSA	0.015	0.08	0.048	0.067	0.127	70
8 - Palo Blanco	0.018	0.11	0.071	0.164	0.134	61
9 - Cooprocam	0.016	0.02	0.046	0.105	0.087	176
10 - Llano Verde	0.009	0.05	0.049	0.050	0.088	67
11 - La Polvosa	0.013	0.24	0.148	0.038	0.094	74
12 - Puente Real	0.020	0.33	0.025	0.005	0.962	61
13 - Los Perejiles	0.007	0.16	0.011	0.026	0.069	65
14 - Torrecillas	0.013	0.27	0.013	0.013	0.117	61

Table 19. Results of 21 November 2001 water quality analyses from sample stations (0.5-m sample depth) in the Estero Real system.

Sample Station	Total Alkalinity (mg/L)	Temperature (ºC)	Salinity (g/L)	Dissolved Oxygen (mg/L)	Settleable Solids (mg/L)	pH	Secchi Disk (cm)	Reactive Silicate (mg/L)
1 - El Chorro	146.00	28.7	29.7	5.83	< 0.5	7.43	55.0	0.213
2 - Dos Aguas Grandes	153.00	28.6	28.5	4.23	< 0.5	7.49	10.0	1.710
3 - Camilo Ortega	147.00	28.7	26.5	3.40	< 0.5	7.44	8.0	2.847
4 - Dos Aguitas	161.00	28.9	25.1	2.89	< 0.5	7.46	8.0	2.601
5 - Puerto .Morazán	164.00	28.7	16.7	1.74	0.5	7.37	10.0	5.037
6 - Estero Palomino	198.00	28.2	10.6	1.35	0.6	7.34	5.0	5.611
7 - FRIXSA	210.00	28.7	8.4	0.77	0.6	7.36	3.0	6.246
8 - Palo Blanco	213.00	28.5	4.3	1.51	< 0.5	7.42	3.0	8.034
9 - Cooprocam	232.00	29.0	3.6	0.65	0.6	7.50	3.0	8.402
10 - Llano Verde	144.00	28.5	1.0	1.69	3.0	7.53	3.0	10.126
11 - La Polvosa	134.50	28.0	0.7	3.31	3.0	7.53	2.0	10.126
12 - Puente Real	213.00	27.6	0.4	2.35	0.6	7.60	7.0	6.761
13 - Los Perejiles	165.00	27.8	18.3	1.34	5.0	7.38	3.0	4.570
14 - Torrecillas	140.00	28.3	27.9	3.95	< 0.5	7.38	10.0	2.708

Sample Station	Total Hardness (mg/L)	Total P (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	Total N (mg/L)	TSS (mg/L)	Chlorophyll *a* (mg/m^3)
1 - El Chorro	4,896	0.000	0.095	0.008	0.009	0.074	0.48	-
2 - Dos Aguas Grandes	3,570	0.001	0.100	0.010	0.021	0.083	0.84	-
3 - Camilo Ortega	3,774	0.001	0.188	0.004	0.025	0.120	0.76	-
4 - Dos Aguitas	4,080	0.001	0.177	0.005	0.022	0.169	0.60	-
5 - Puerto .Morazán	3,264	0.006	0.267	0.007	0.038	0.214	0.60	-
6 - Estero Palomino	3,978	0.007	0.198	0.011	0.030	0.049	0.28	-
7 - FRIXSA	3,774	0.009	0.118	0.004	0.039	0.082	0.28	-
8 - Palo Blanco	3,366	0.011	0.014	0.017	N.D.	0.094	0.24	-
9 - Cooprocam	1,938	0.014	0.075	0.034	0.055	0.068	0.52	-
10 - Llano Verde	1,122	0.015	0.128	0.031	0.119	0.140	0.40	-
11 - La Polvosa	612	0.016	0.110	0.036	0.105	0.116	0.48	-
12 - Puente Real	3,774	0.013	0.221	0.004	0.139	0.099	0.08	-
13 - Los Perejiles	4,692	0.007	0.259	0.008	0.071	0.564	0.20	-
14 - Torrecillas	4,080	0.002	0.208	0.006	0.040	0.076	0.72	-

Table 20. Results of microbiological analyses of water samples collected from the Estero Real system, Nicaragua, during the period March – November 2001.

Sample Station	Variable	Mar 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01
El Chorro (M1)	Total bacteria count (CFU/mL)	4.6×10^4	4.8×10^4	3.0×10^4	3.5×10^4	1.2×10^3	2.4×10^3	2.6×10^3	8.0×10^3
Camilo Ortega (M2)	Total bacteria count (CFU/mL)	2.5×10^4	1.6×10^4	3.0×10^3	2.0×10^4	2.1×10^4	1.0×10^3	2.0×10^3	1.9×10^3
Puerto Morazán (M3)	Total bacteria count (CFU/mL)	5.1×10^4	6.6×10^4	2.1×10^4	5.0×10^3	2.6×10^5	9.0×10^4	9.6×10^3	2.0×10^3
COOPROCAM (M4)	Total bacteria count (CFU/mL)		2.2×10^4	4.0×10^4	1.2×10^4	1.7×10^4	2.0×10^3	6.7×10^3	2.0×10^3
Torrecilla (M5)	Total bacteria count (CFU/mL)			1.3×10^4	6.2×10^3	7.2×10^4	1.0×10^4	7.4×10^3	1.3×10^4
Los Perejiles (M6)	Total bacteria count (CFU/mL)			5.1×10^3	2.2×10^4	8.2×10^4	4.0×10^4	5.0×10^4	1.5×10^4
El Chorro (M1)	Total coliforms (MPN/100 mL)	11	4	460	240	1,100	23	9	1,100
Camilo Ortega (M2)	Total coliforms (MPN/100 mL)	21	4	240	460	1,100	93	23	460
Puerto Morazán (M3)	Total coliforms (MPN/100 mL)	1,100	460	1,100	1,100	1,100	1,100	240	460
COOPROCAM (M4)	Total coliforms (MPN/100 mL)		460	460	240	1,100	460	460	43
Torrecilla (M5)	Total coliforms (MPN/100 mL)			1,100	240	1,100	39	43	1,100
Los Perejiles (M6)	Total coliforms (MPN/100 mL)			1,100	460	1,100	43	1,100	240
El Chorro (M1)	Fecal coliforms (MPN/100 mL)		3	240	240	1,100	4	9	240
Camilo Ortega (M2)	Fecal coliforms (MPN/100 mL)		3	240	240	1,100	9	23	43
Puerto Morazán (M3)	Fecal coliforms (MPN/100 mL)		93	1,100	1,100	1,100	1,100	240	460
COOPROCAM (M4)	Fecal coliforms (MPN/100 mL)		23	240	240	1,100	7	240	43
Torrecilla (M5)	Fecal coliforms (MPN/100 mL)			1,100	240	1,100	9	15	93
Los Perejiles (M6)	Fecal coliforms (MPN/100 mL)			1,100	240	1,100	43	1,100	240
El Chorro (M1)	*Vibrio* sp. (CFU/mL)	10	10	70	11	150	10	20	50
Camilo Ortega (M2)	*Vibrio* sp. (CFU/mL)	10	10	30	70	20	30	50	10
Puerto Morazán (M3)	*Vibrio* sp. (CFU/mL)	10	10	20	20	220	30	50	100
COOPROCAM (M4)	*Vibrio* sp. (CFU/mL)		15	10	20	10	30	80	50
Torrecilla (M5)	*Vibrio* sp. (CFU/mL)			12	20	150	10	60	80
Los Perejiles (M6)	*Vibrio* sp. (CFU/mL)			18	10	300	200	1.5×10^3	12

Table 20. Continued.

Sample Station	Variable	Mar 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01
El Chorro (M1)	*Vibrio cholerae* (CFU/mL)	Negative	Negative	Positive	Positive	Positive	Positive	Negative	Negative
Camilo Ortega (M2)	*Vibrio cholerae* (CFU/mL)	Negative	Negative	Positive	Positive	Positive	Positive	Positive	Negative
Puerto Morazán (M3)	*Vibrio cholerae* (CFU/mL)	Negative	Positive	Positive	Positive	Positive	Positive	Negative	Negative
COOPROCAM (M4)	*Vibrio cholerae* (CFU/mL)		Negative	Positive	Positive	Positive	Positive	Negative	Negative
Torrecilla (M5)	*Vibrio cholerae* (CFU/mL)			Positive	Positive	Positive	Positive	Positive	Negative
Los Perejiles (M6)	*Vibrio cholerae* (CFU/mL)			Positive	Positive	Positive	Positive	Positive	Negative
El Chorro (M1)	Salmonella (CFU/mL)					Negative	Positive	Positive	Positive
Camilo Ortega (M2)	Salmonella (CFU/mL)					Negative	Positive	Negative	Negative
Puerto Morazán (M3)	Salmonella (CFU/mL)					Negative	Negative	Negative	Negative
COOPROCAM (M4)	Salmonella (CFU/mL)					Negative	Negative	Negative	Negative
Torrecilla (M5)	Salmonella (CFU/mL)					Negative	Negative	Negative	Negative
Los Perejiles (M6)	Salmonella (CFU/mL)					Negative	Negative	Negative	Negative

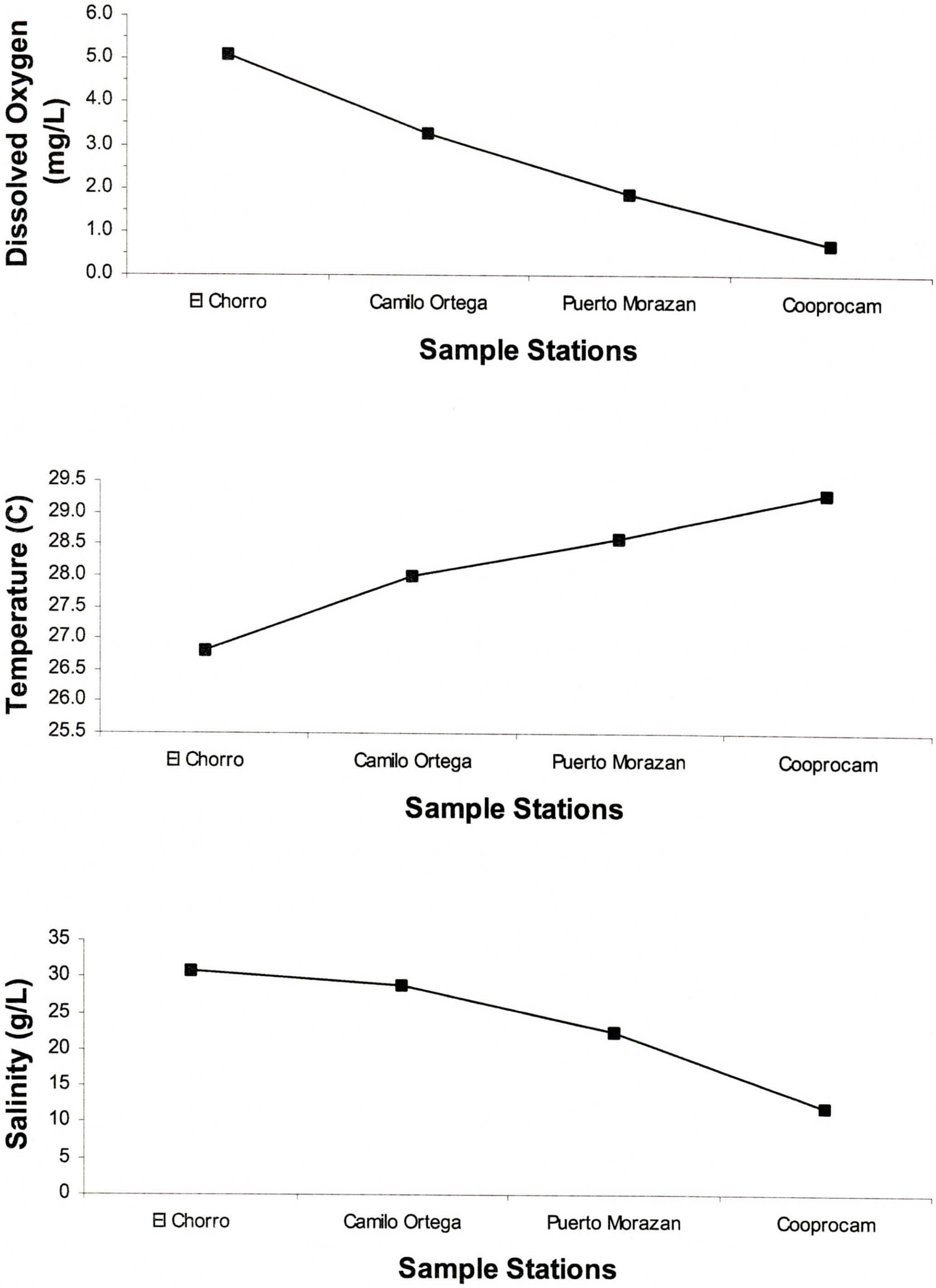


Figure 3. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 16 January 2001.

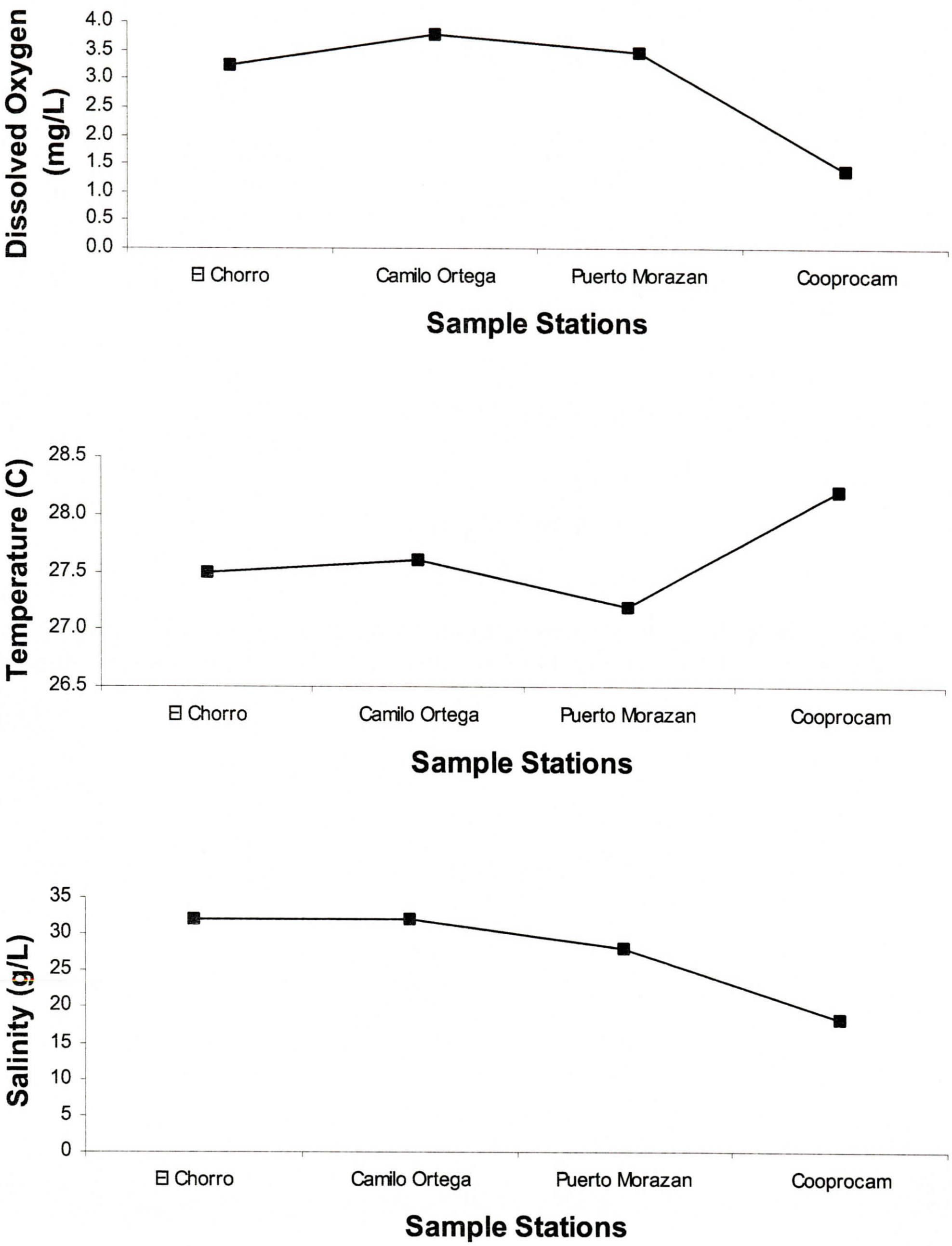


Figure 4. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 13 February 2001.

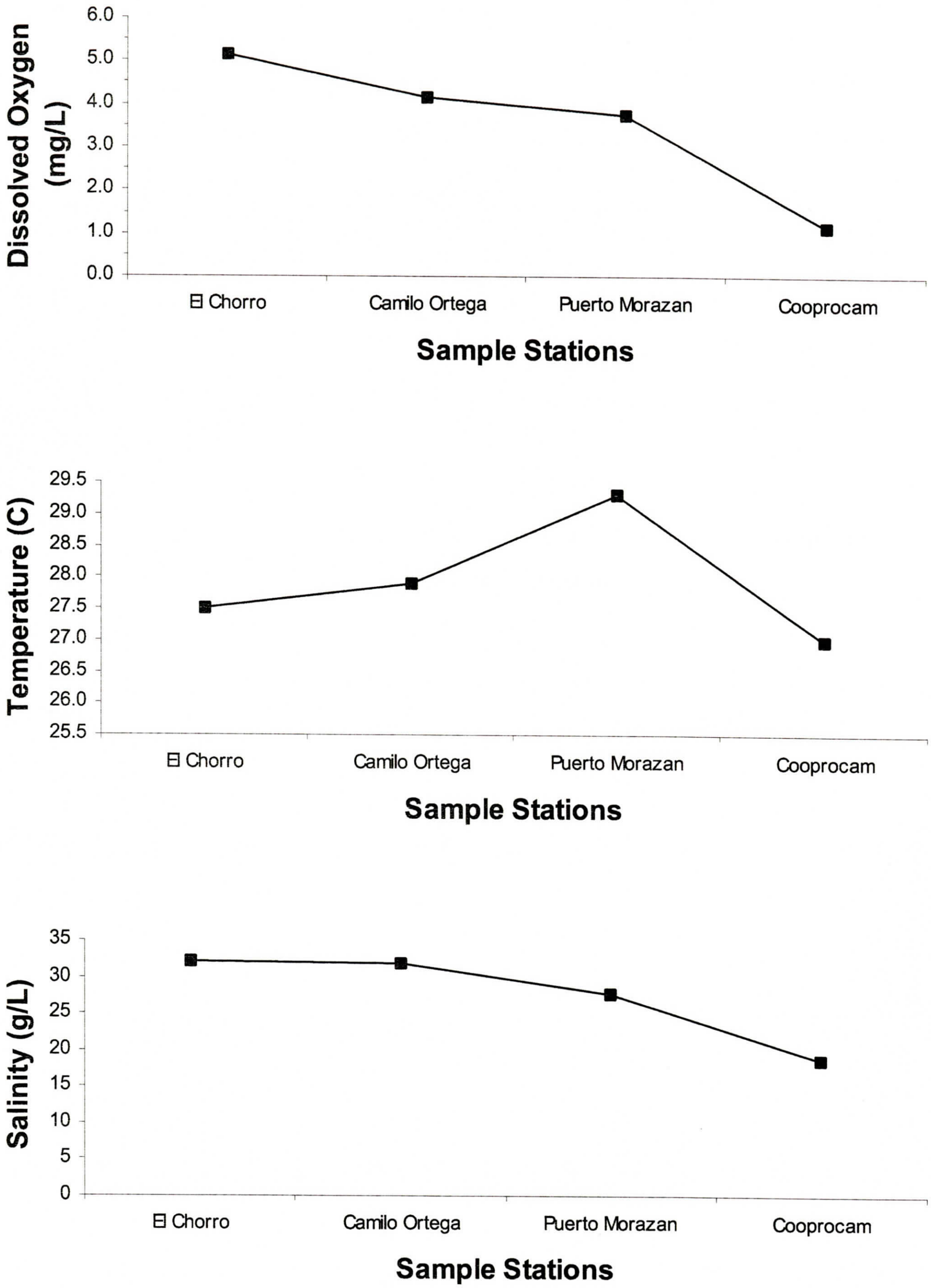


Figure 5. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 26 March 2001.

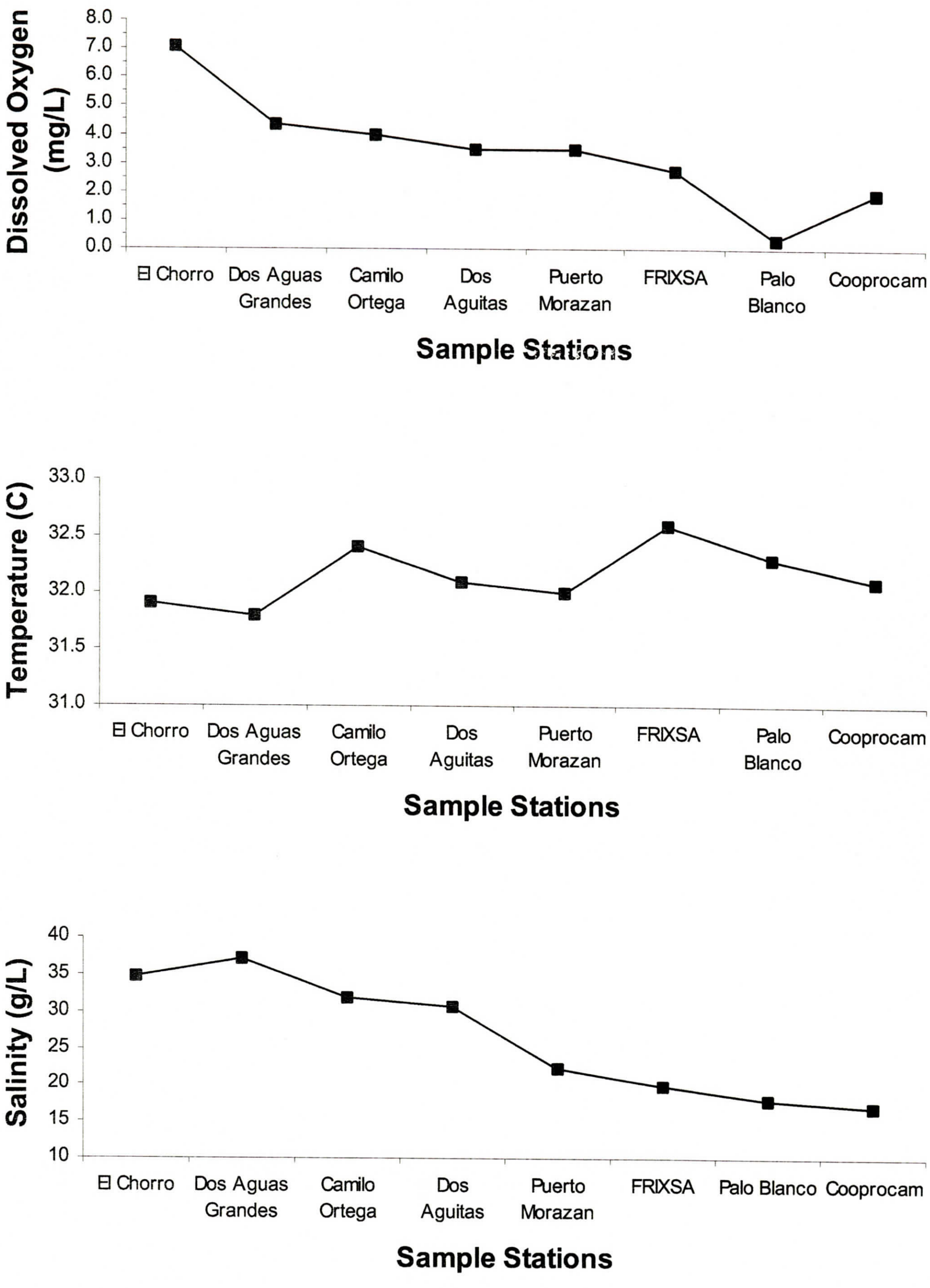


Figure 6. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 15 May 2001.

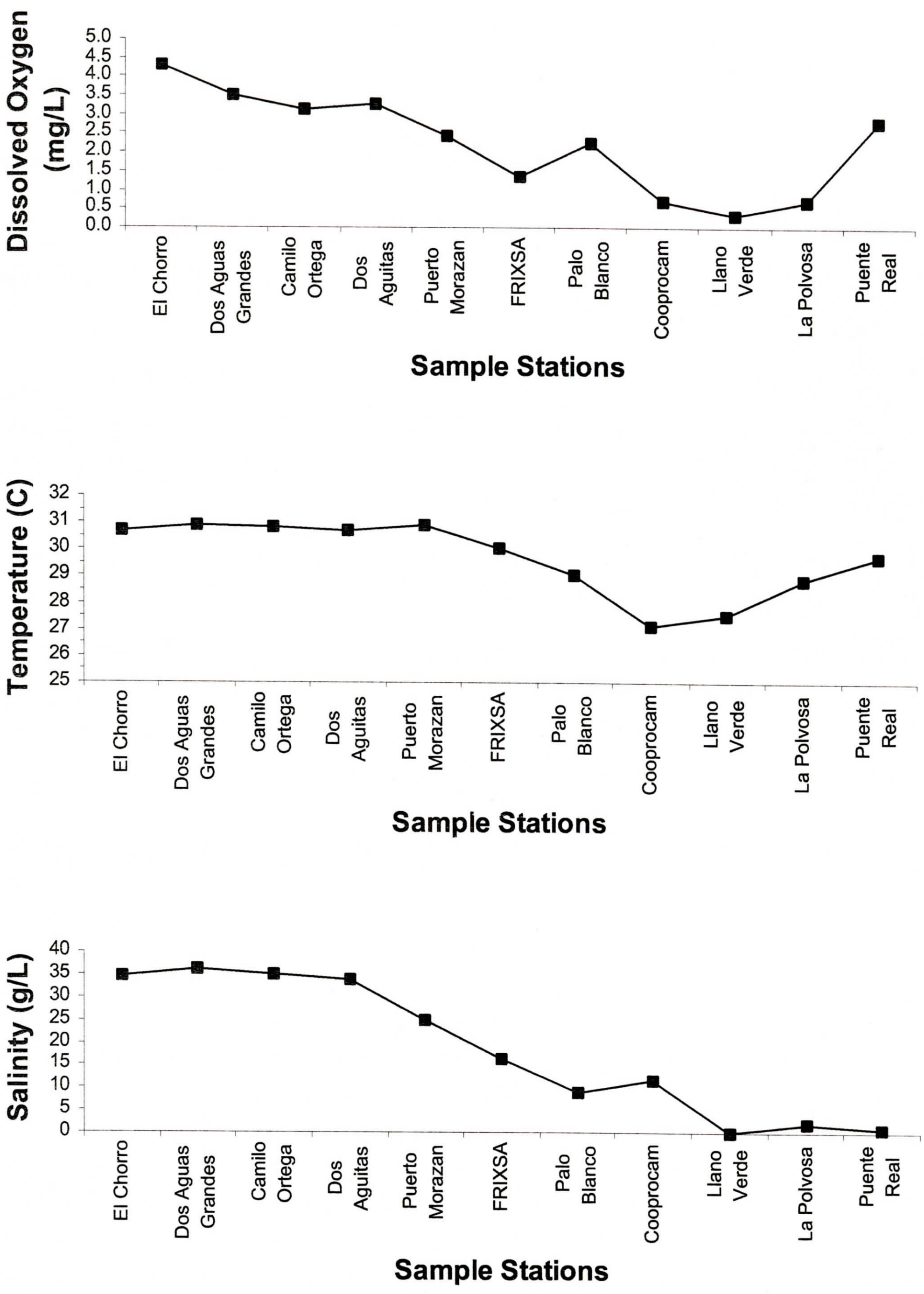


Figure 7. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 24 May 2001.

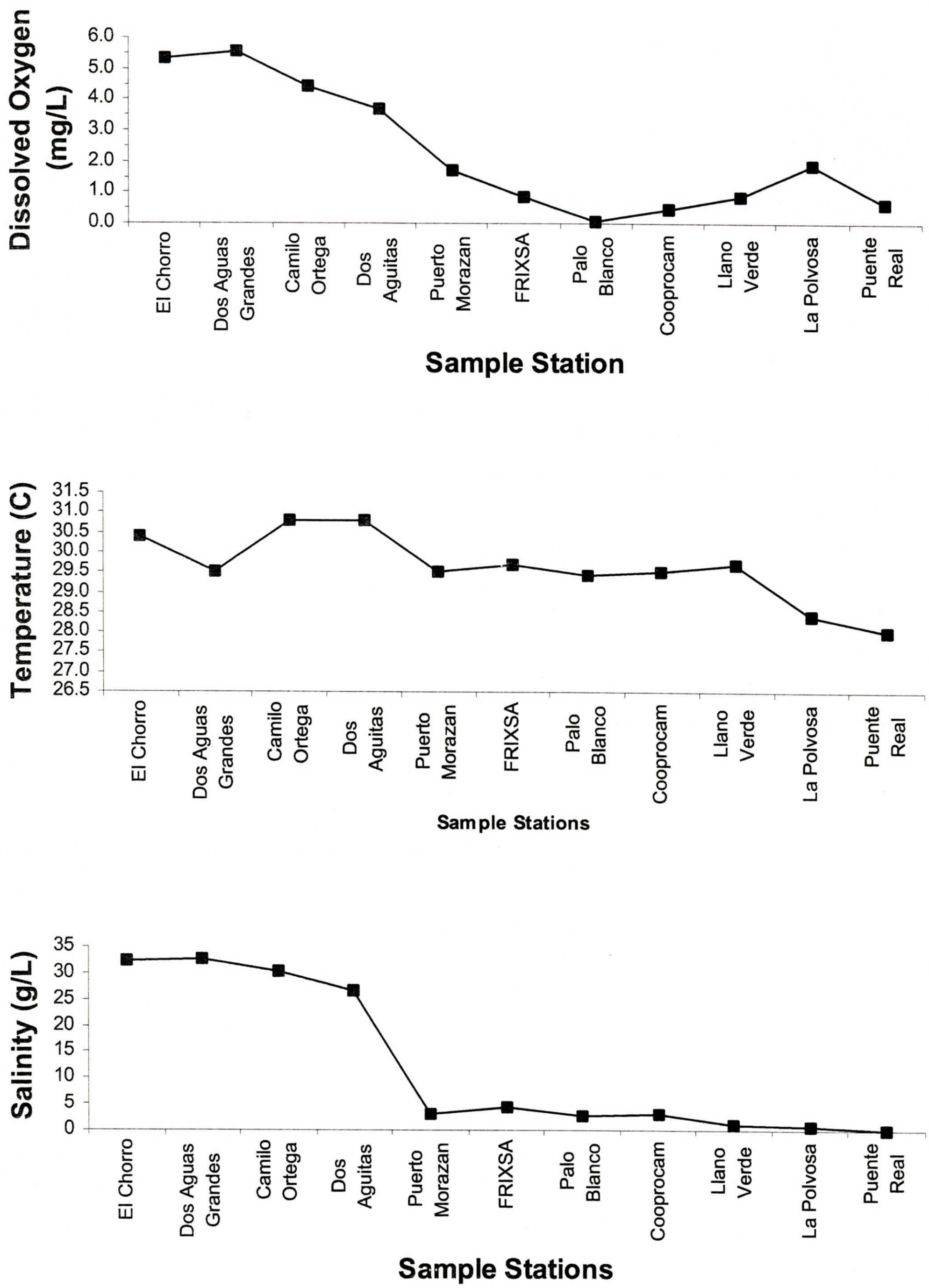


Figure 8. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 7 June 2001.

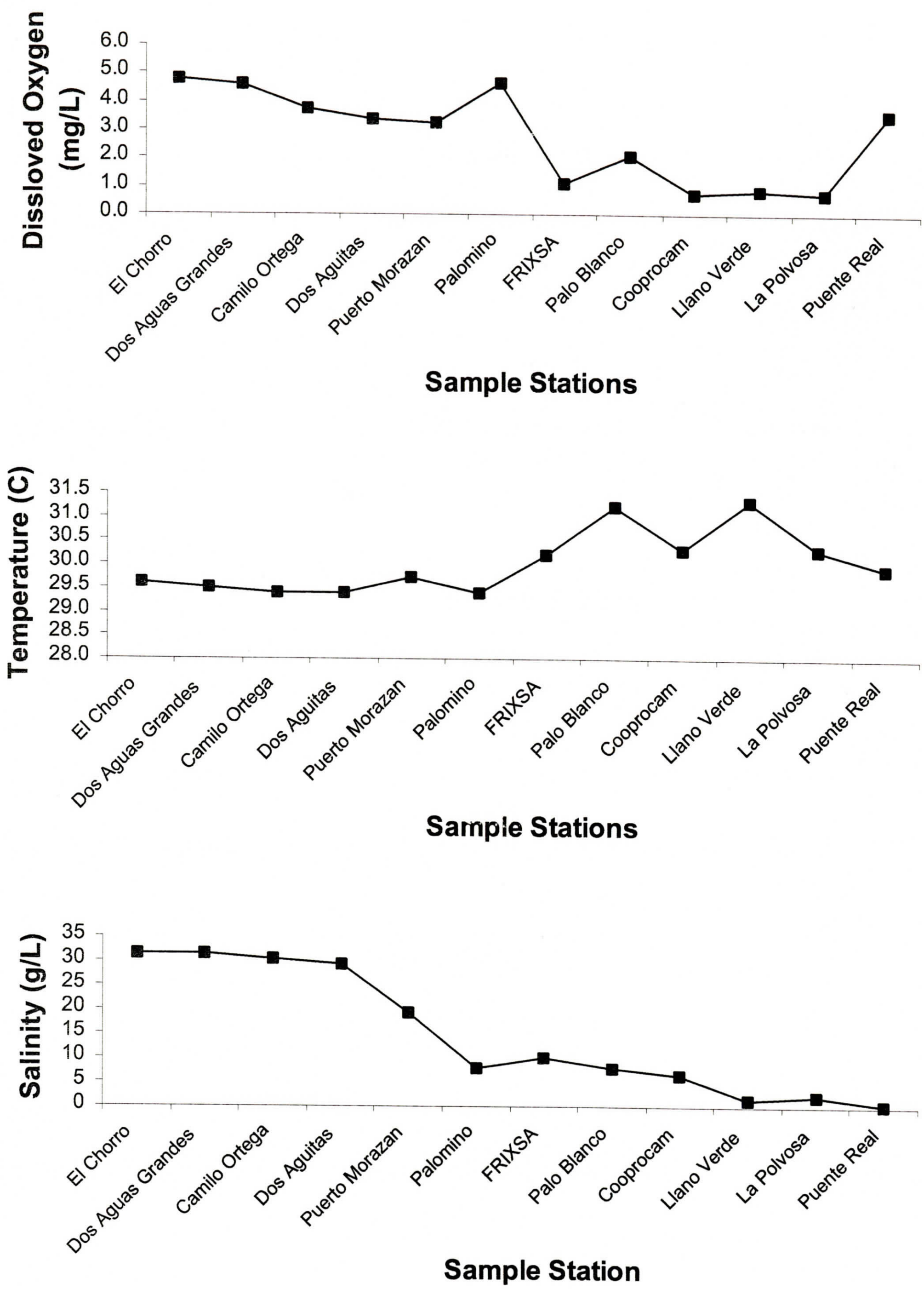


Figure 9. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 25 June 2001.

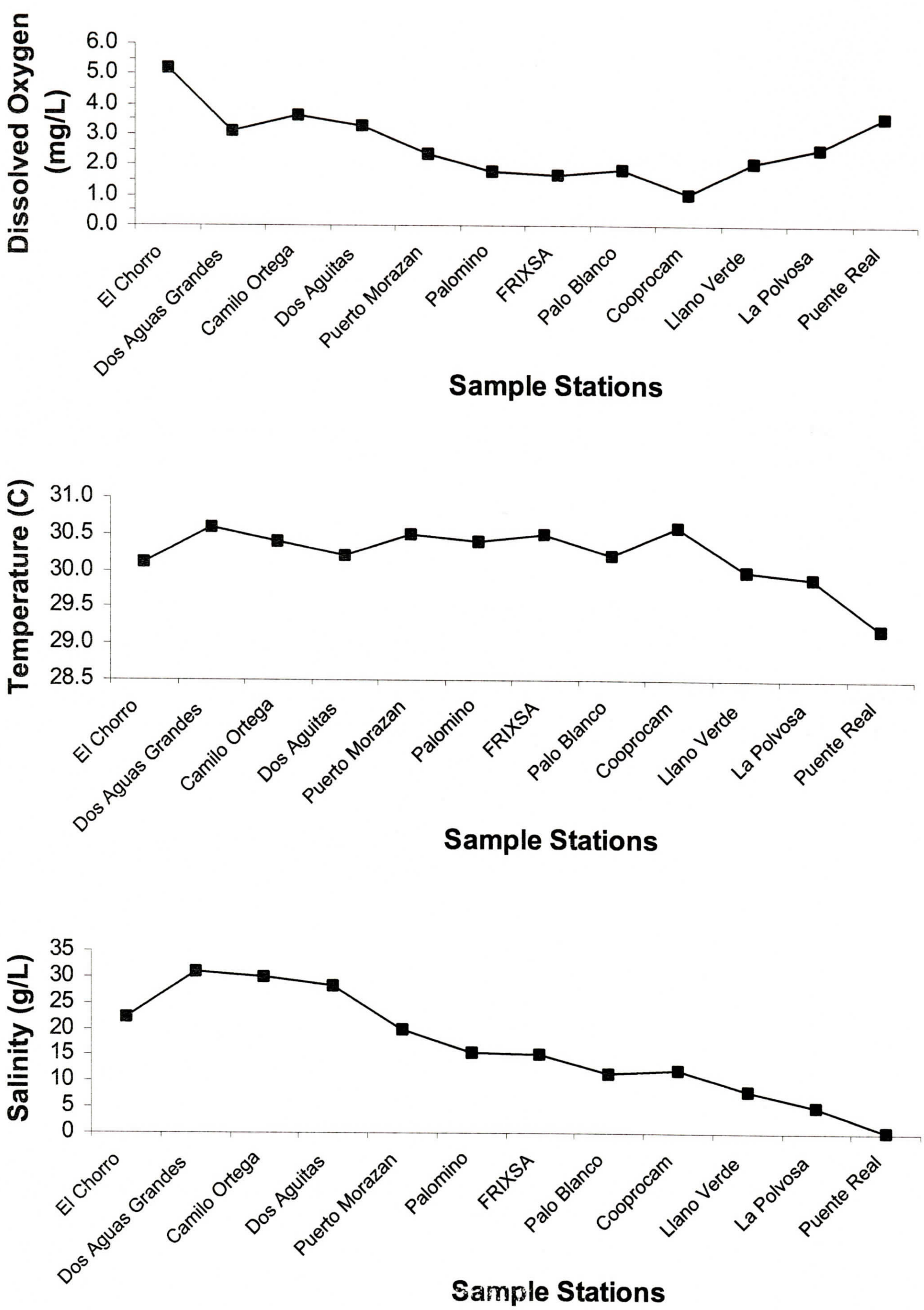


Figure 10. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 9 July 2001.

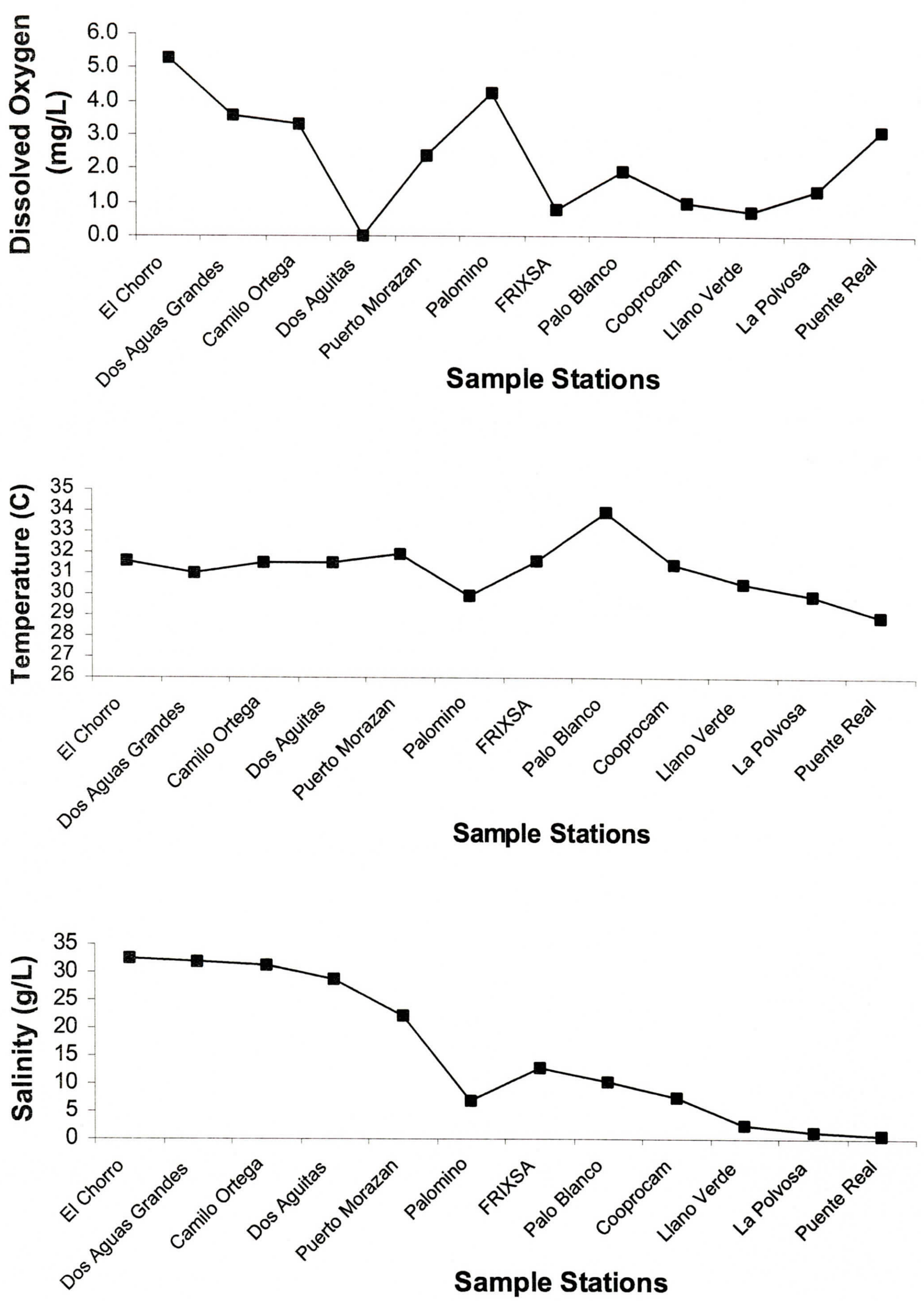


Figure 11. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 27 July 2001.

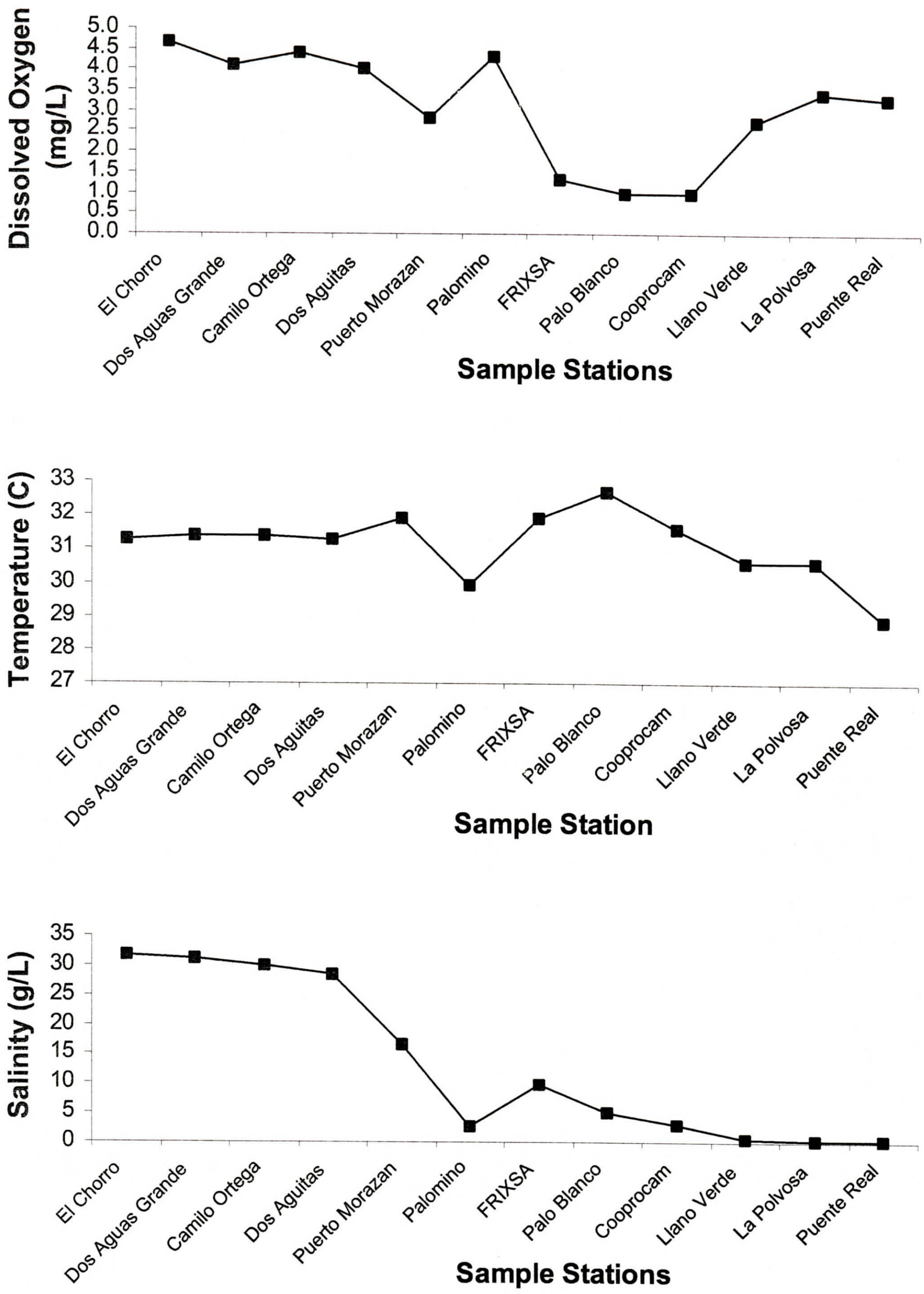


Figure 12. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 7 August 2001.

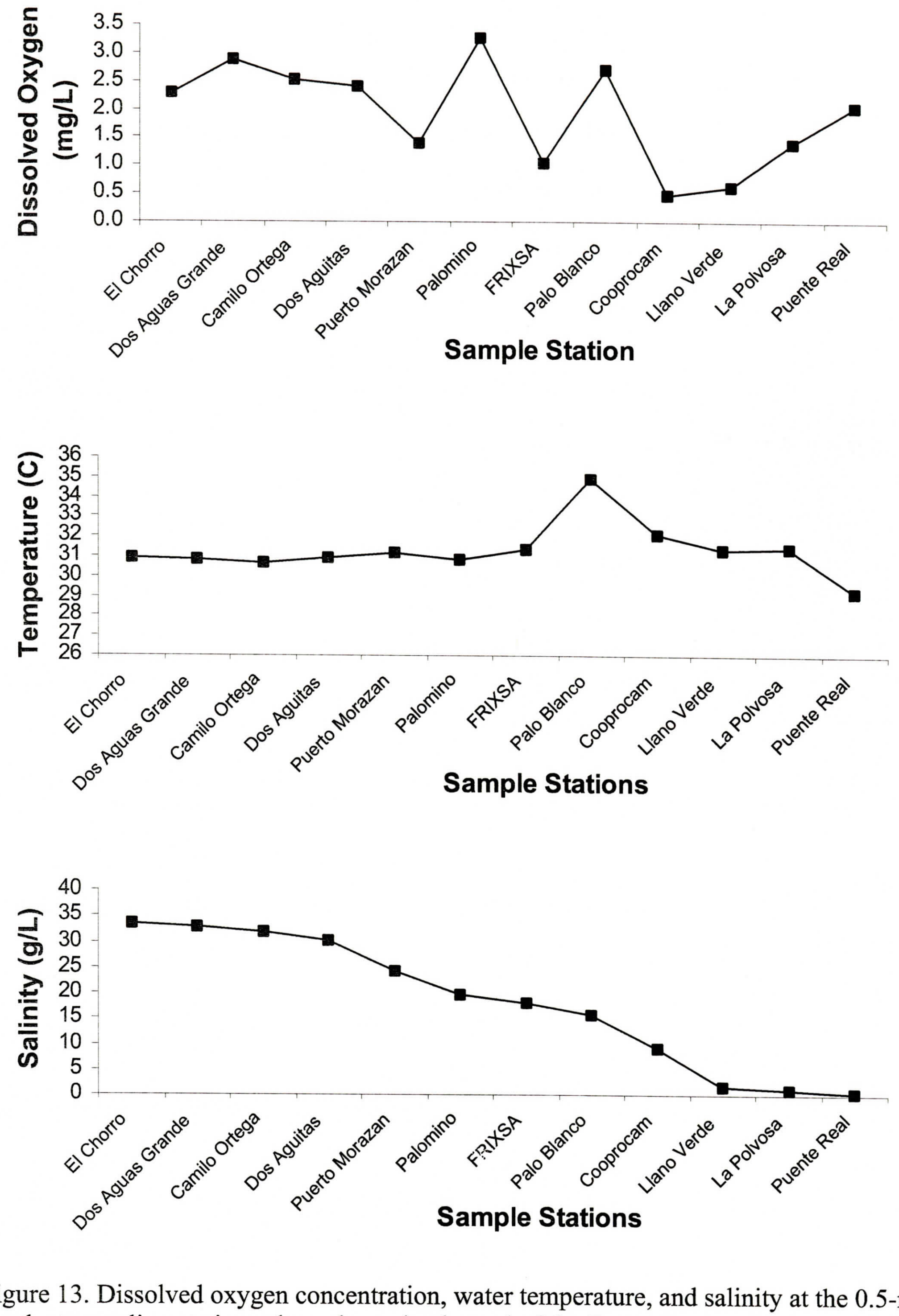


Figure 13. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 22 August 2001.

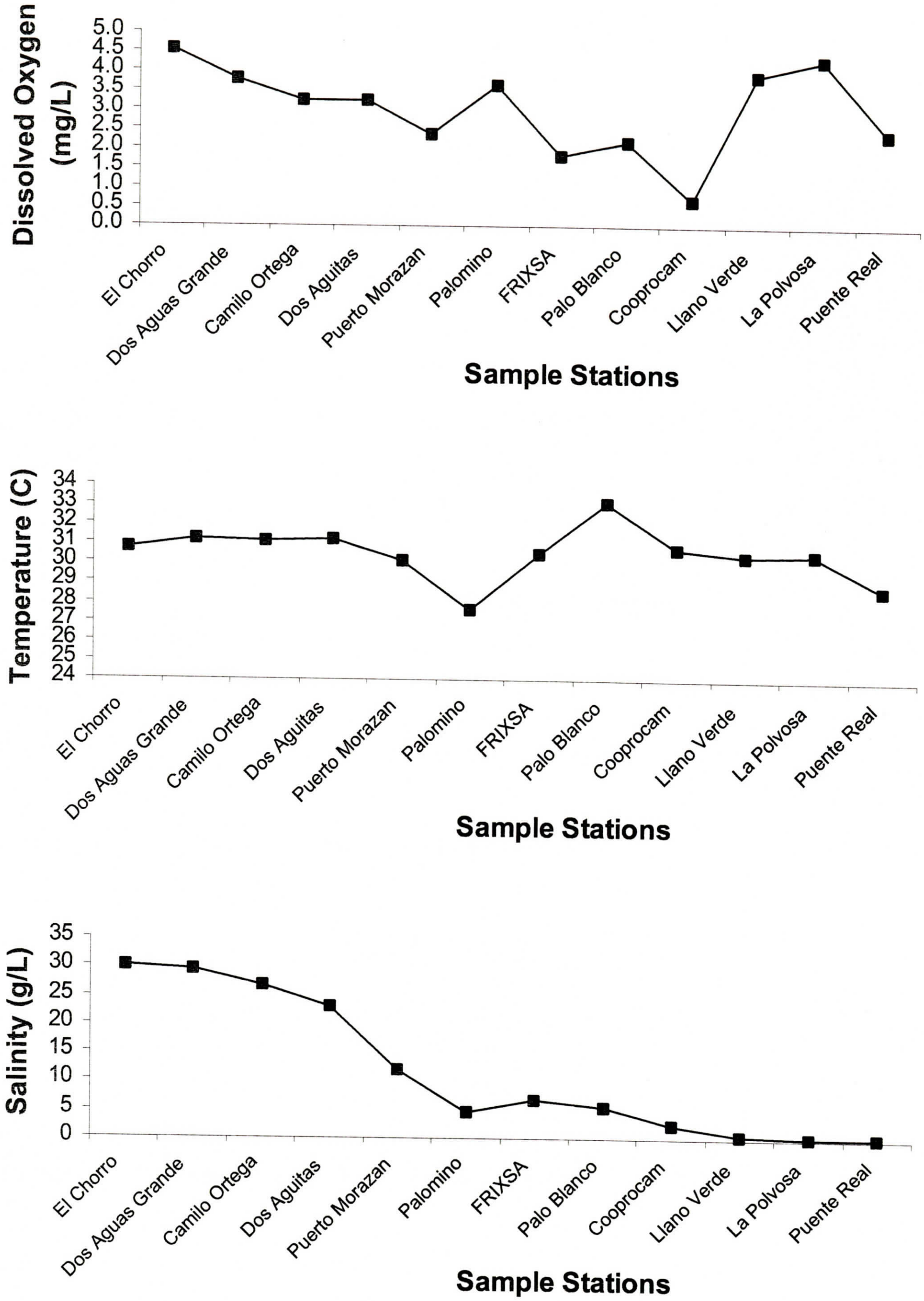


Figure 14. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 5 September 2001.

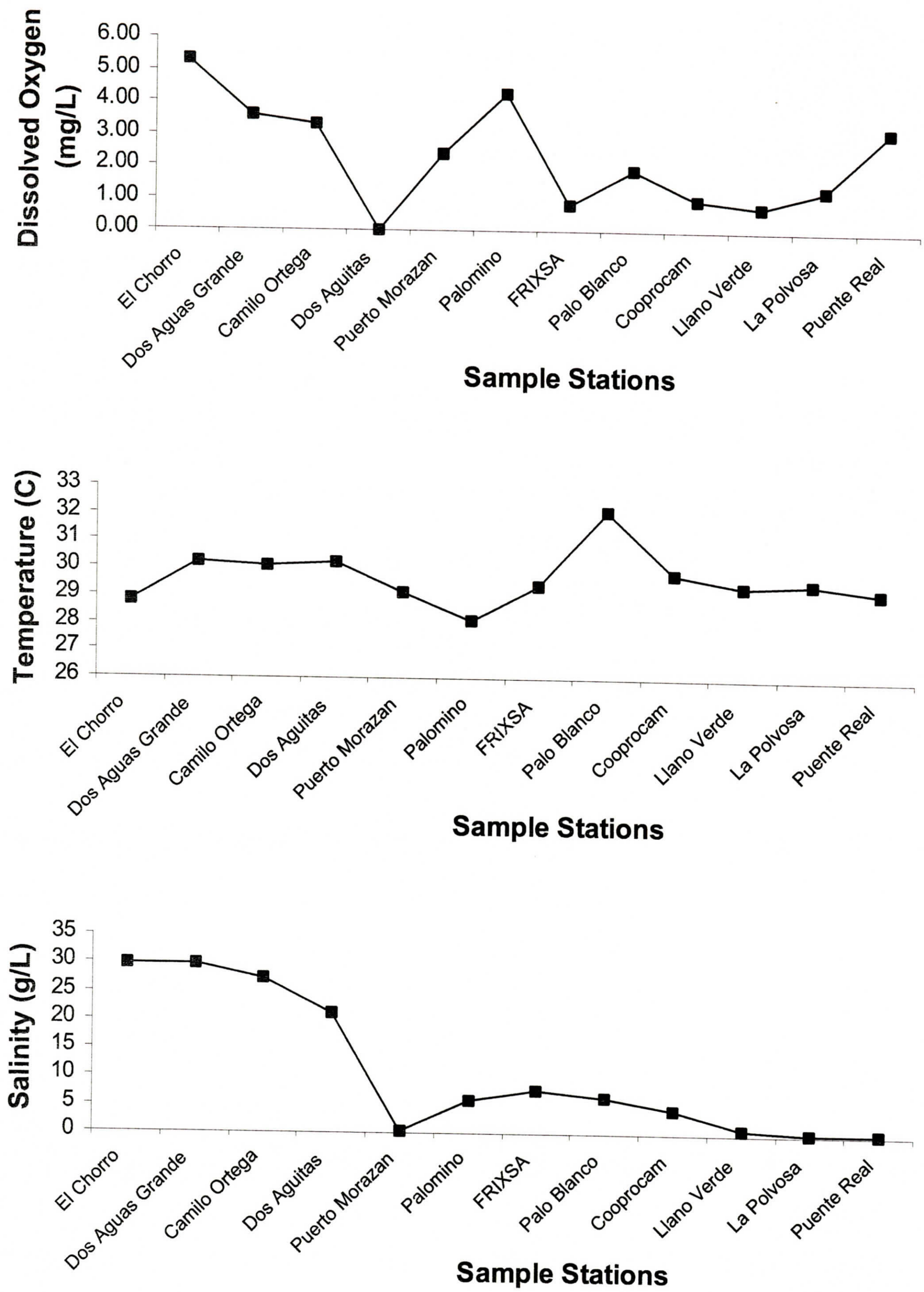


Figure 15. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 19 September 2001.

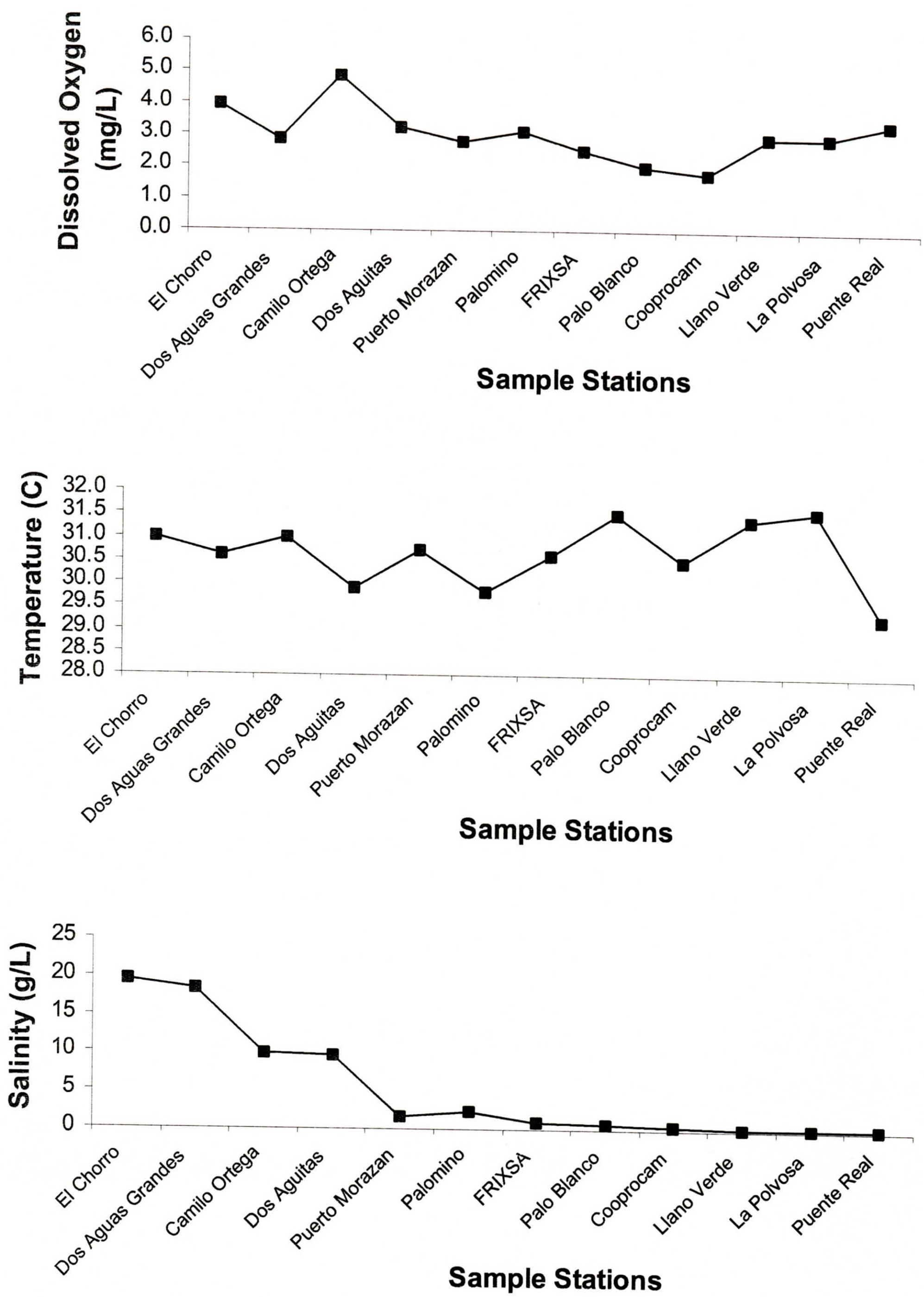


Figure 16. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 3 October 2001.

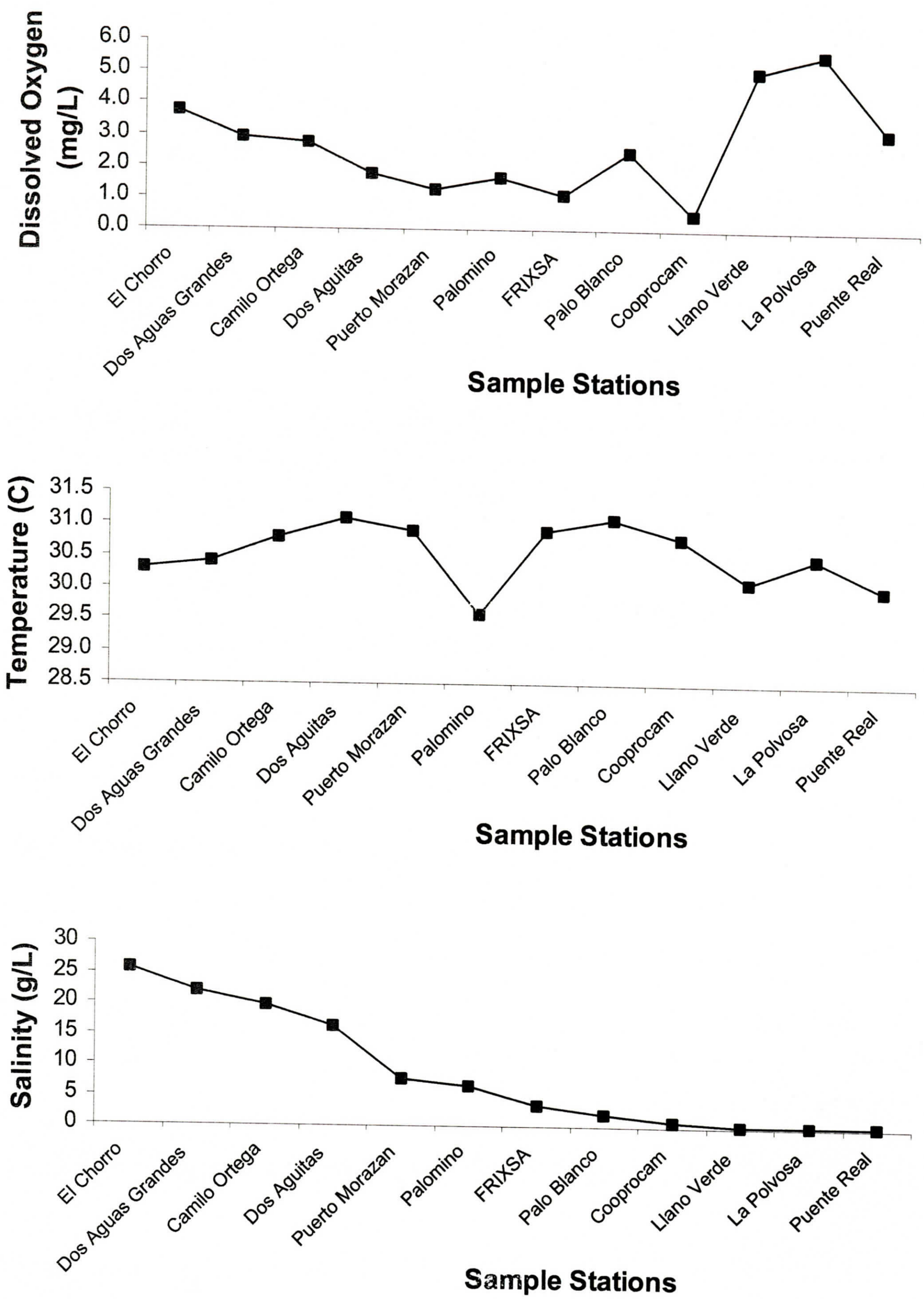


Figure 17. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 17 October 2001.

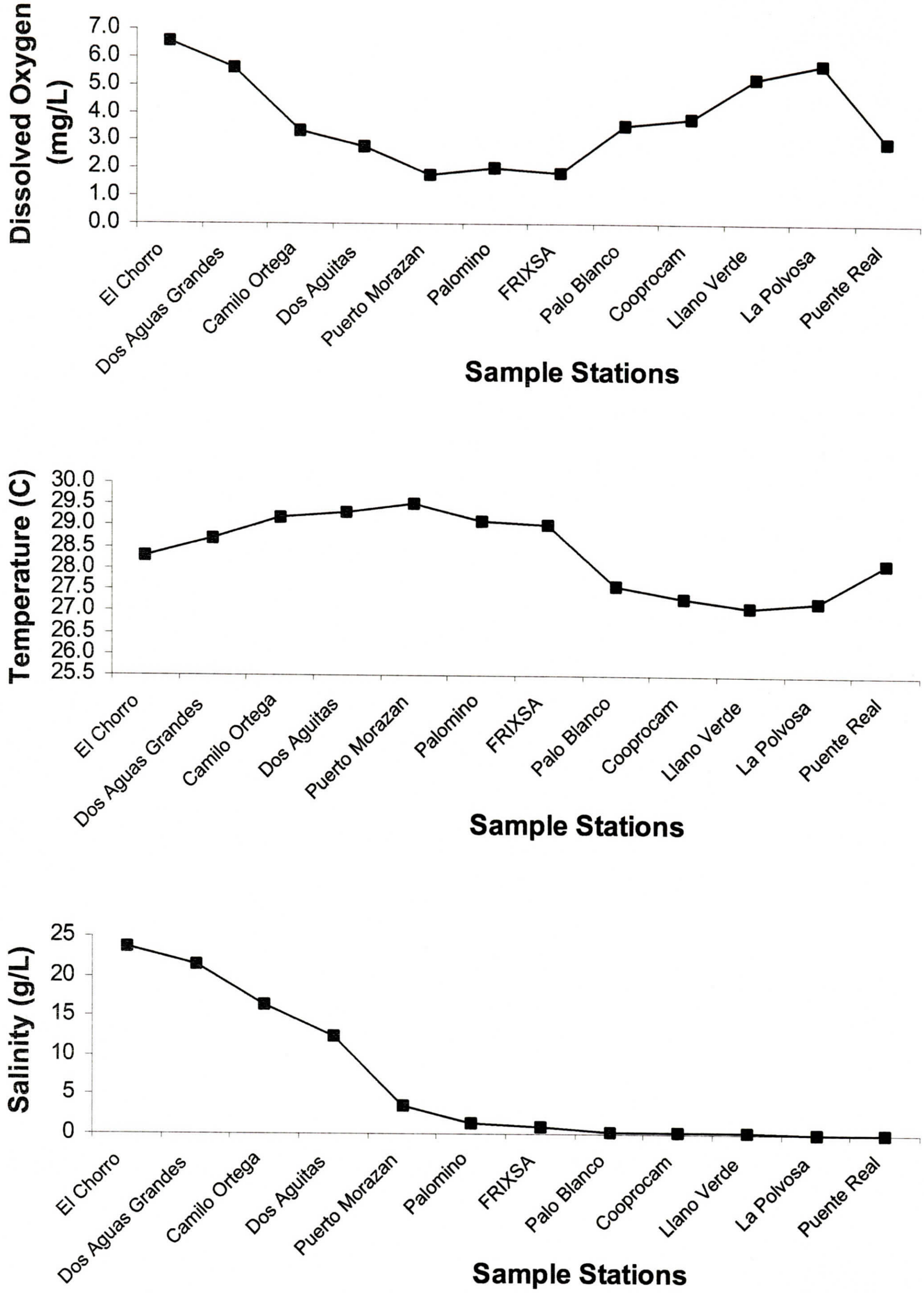


Figure 18. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 7 November 2001.

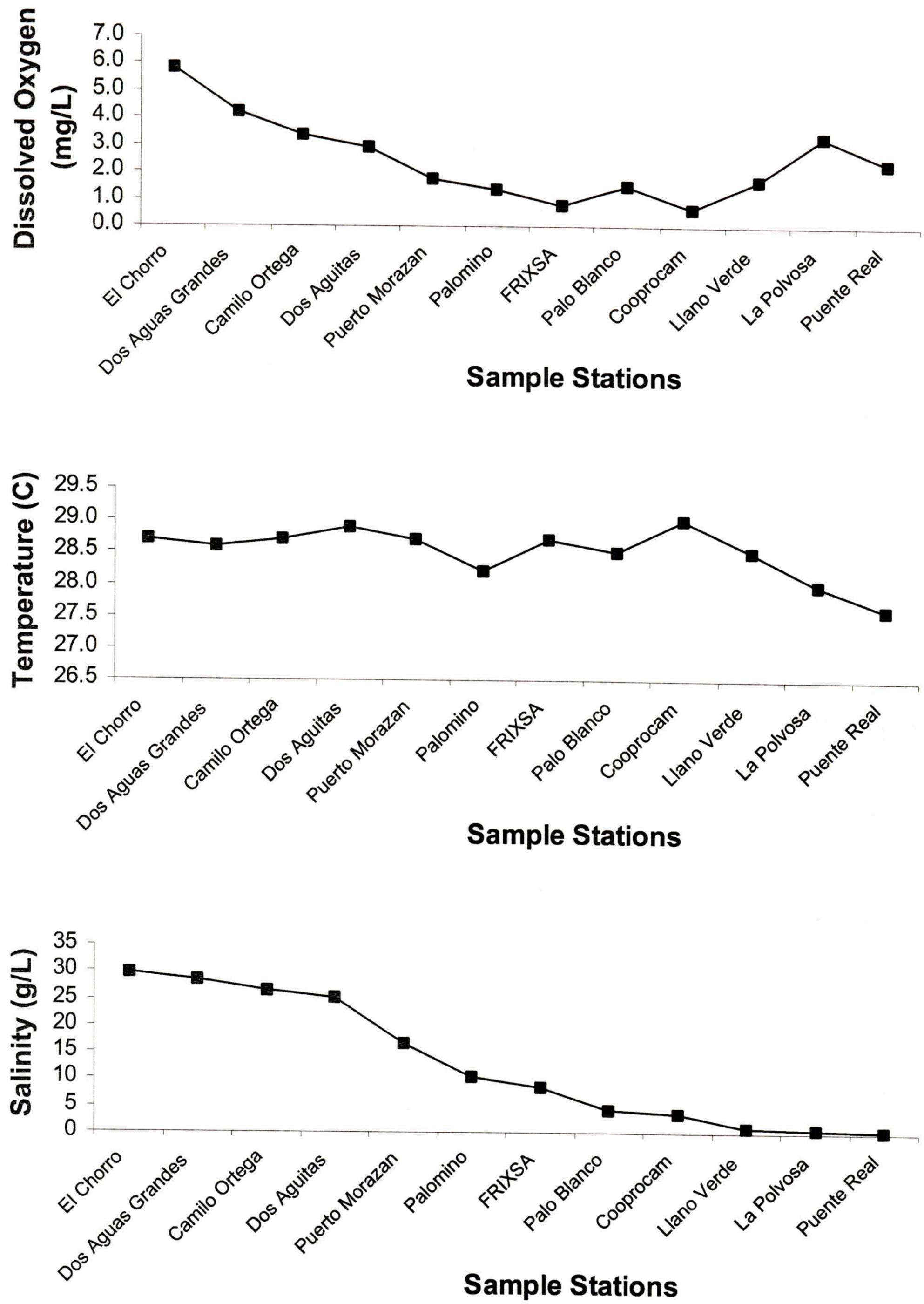


Figure 19. Dissolved oxygen concentration, water temperature, and salinity at the 0.5-m depth at sampling stations along the main channel of the Estero Real on 19 November 2001.

ESTUARINE ASSIMILATIVE CAPACITY

While determination of the assimilative capacity of the Estero Real exceeds the scope and budget of the current project, collection of some data critical to this determination was initiated as part of the current project. Such data collection will facilitate completion of a future project to estimate assimilative capacity of the Estero Real once funding is secured. Immediate application of data collected as part of the current project will be to increase understanding of dissolved oxygen, temperature, and salinity vertical profiles, current velocities, channel morphology, and relative tide heights along the Estero Real. However, real use of data collected during the current project will be determination of Estero Real assimilative capacity, which only is possible in a future, independently funded project.

Dissolved Oxygen/Temperature/Salinity Profiles

Dissolved oxygen/temperature/salinity (DO/T/Sal) profiles were measured *in situ* monthly from June through November 2001 at the 11 stations along the Estero Real main channel (Tables 1 and 2). Measurements at each station were taken just below the water surface and at 0.5-m depth intervals from the water surface to the bottom of the estuary using a YSI model 85 dissolved oxygen/temperature/ salinity meter; the meter probe is equipped with a 30.5-m cable. The boat was anchored at mid-channel during data collection. The DO/T/Sal profiles were repeated on consecutive high and low (or low and high) tides during each monthly sampling.

Results and Discussion

Dissolved oxygen and salinity profiles for high and low tides at each sample station on each sample date are shown in Figures 20 – 31. Water column dissolved oxygen concentrations were less than 3 mg/L from the FRIXSA sampling station to the La Polvosa sampling station in June 2001. During July 2001, DO profiles < 3 mg/L were observed from the Puerto Morazan to La Polvosa sampling stations. The region of water column DO concentrations less than 3 mg/L extended from the Dos Aguas Grandes to the La Polvosa sampling stations during the August 2001 sample. In September, DO concentrations < 3 mg/L in the water column were observed from the Palomino to the La Polvosa sampling stations. However, the water column DO concentrations were increasing and approaching 3 mg/L at the Llano Verde and La Polvosa sampling stations. Water column DO profiles < 3 mg/L were observed from the Dos Aguitas to the COOPROCAM sampling stations during the October 2001 sample. While the low tide DO profiles at the Llano Verde and La Polvosa sample stations in October, the high tide DO profiles were greater than 3 mg/L. In November, the region of water column DO concentrations < 3 mg/L extended from the Dos Aguitas to the Llano Verde sample stations. The low tide DO profile at the La Polvosa sample station was < 3 mg/L in November, but the high tide DO profile was about 3 mg/L from top to bottom.

Salinity profiles varied each month. Salinity was highest in the main channel of the Estero Real during August 2001, and lowest during October 2001. Salinity decreased in the monthly samples from August to October in the following order: July, June, September, and November. The height of the tide and the volume of river discharge and watershed runoff were factors that affected salinity in the Estero Real.

Figure 20. Dissolved oxygen profiles at high and low tide on 25-26 June 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

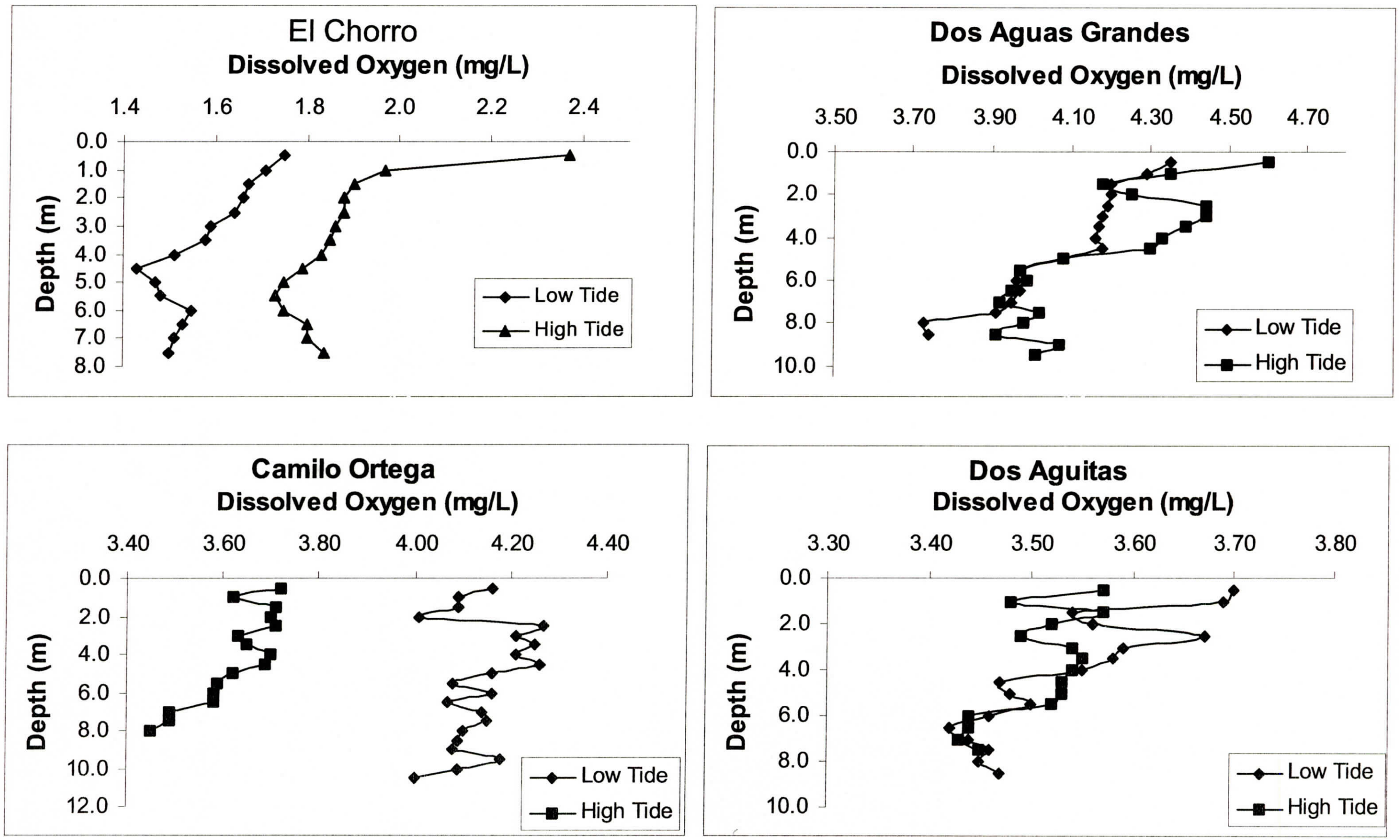


Figure 20-continued. Dissolved oxygen profiles at high and low tide on 25-26 June 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

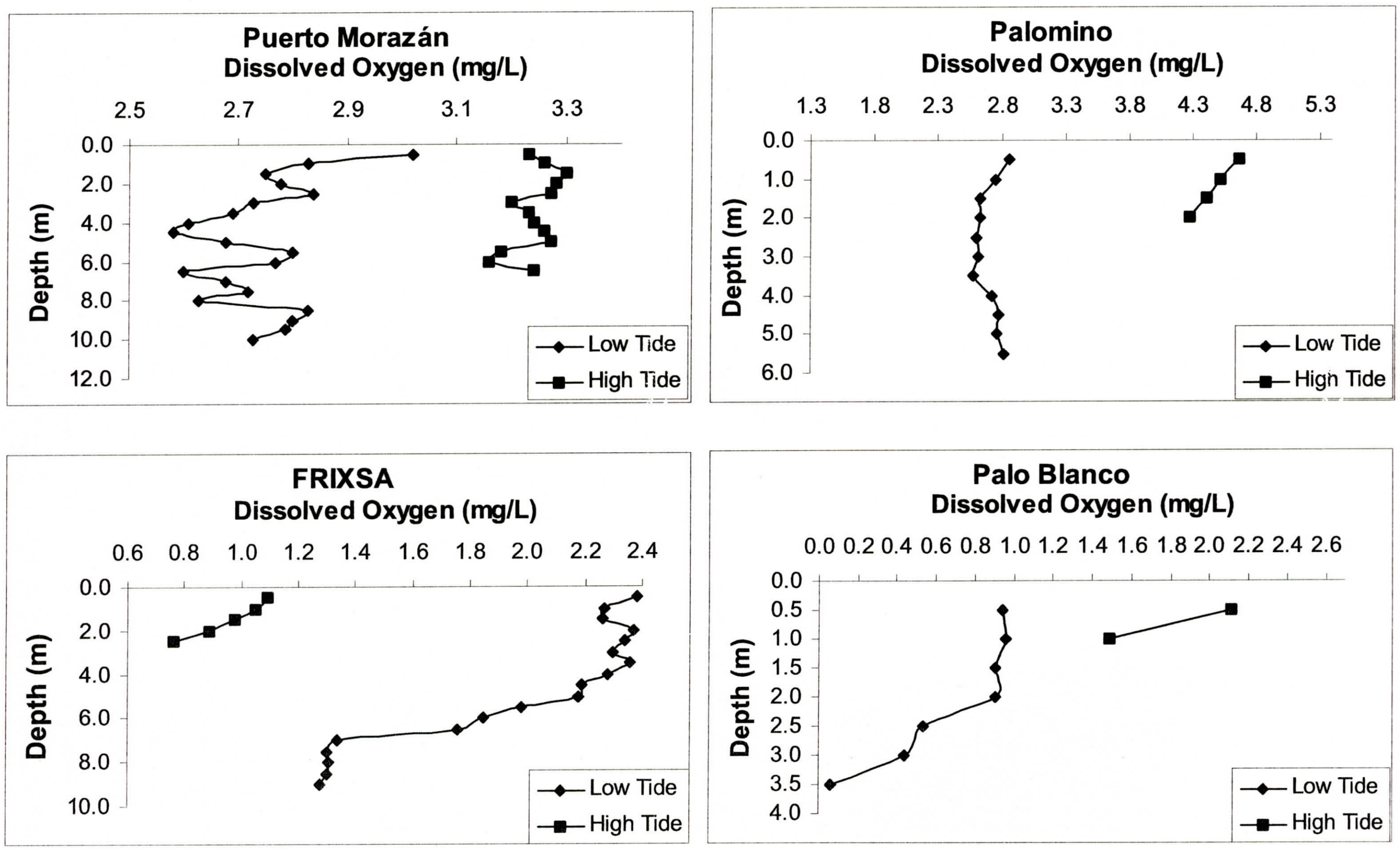


Figure 20 - continued. Dissolved oxygen profiles at high and low tide on 25-26 June 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

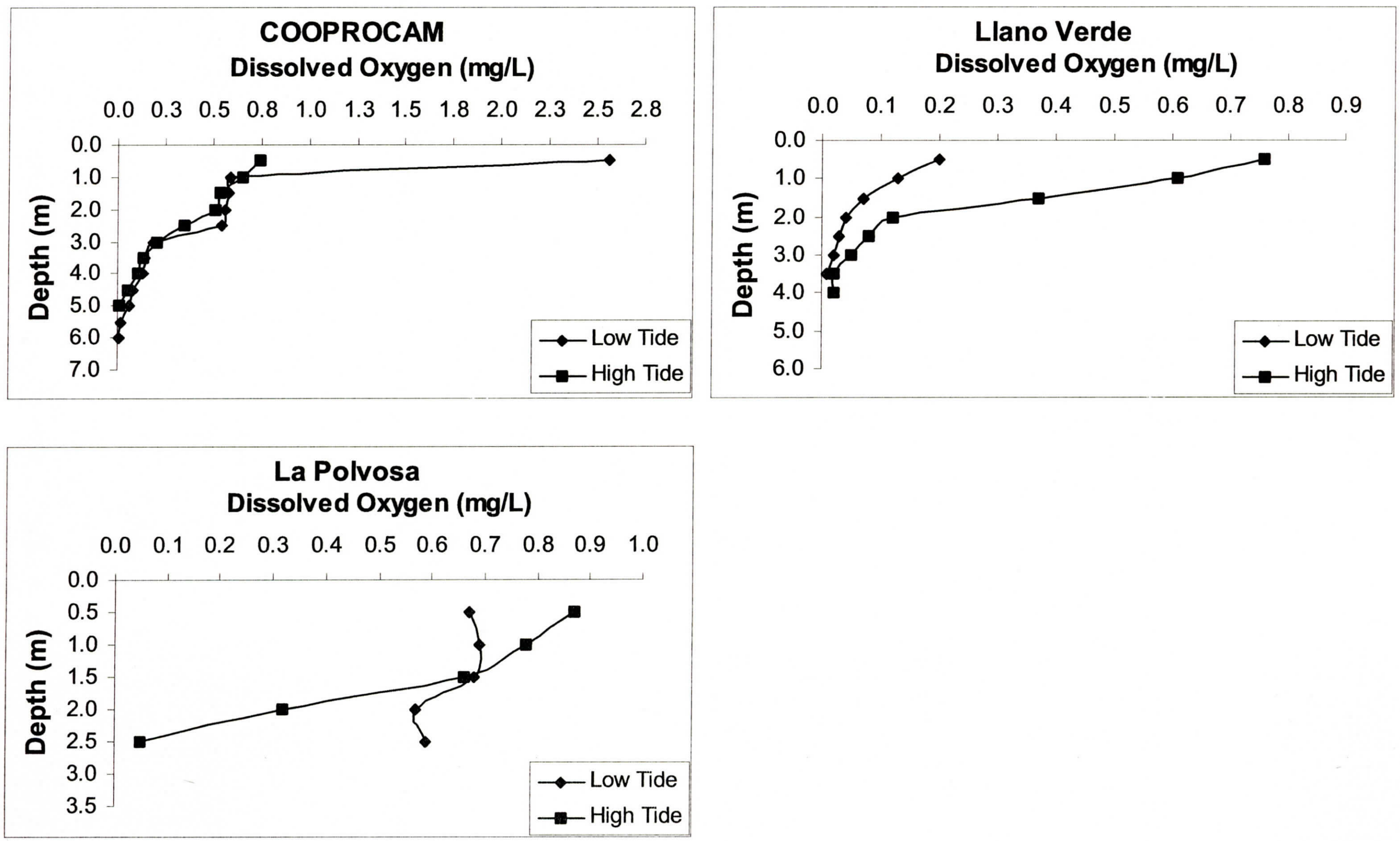


Figure 21. Salinity profiles at high and low tide on 25-26 June 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

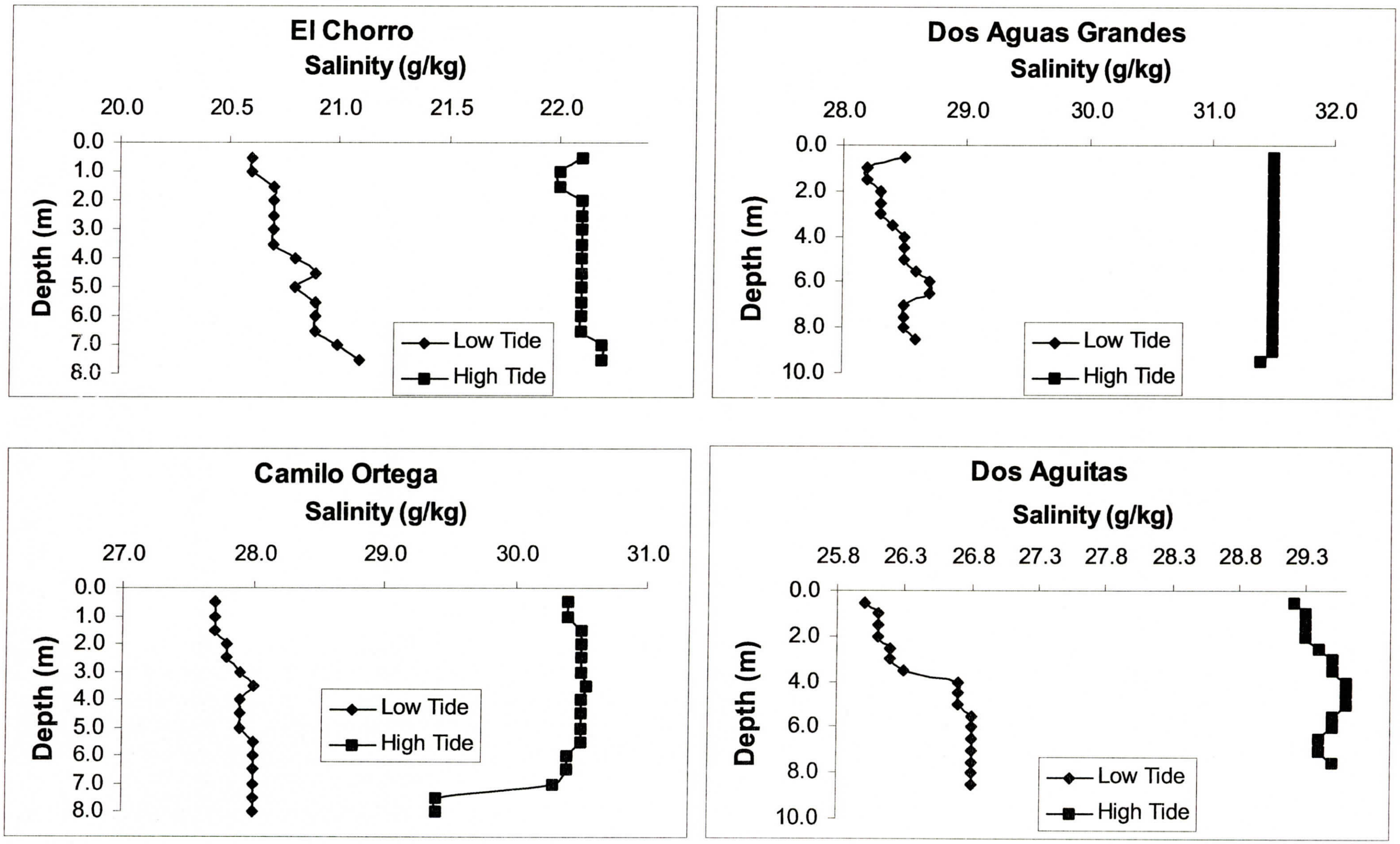


Figure 21 - continued. Salinity profiles at high and low tide on 25-26 June 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

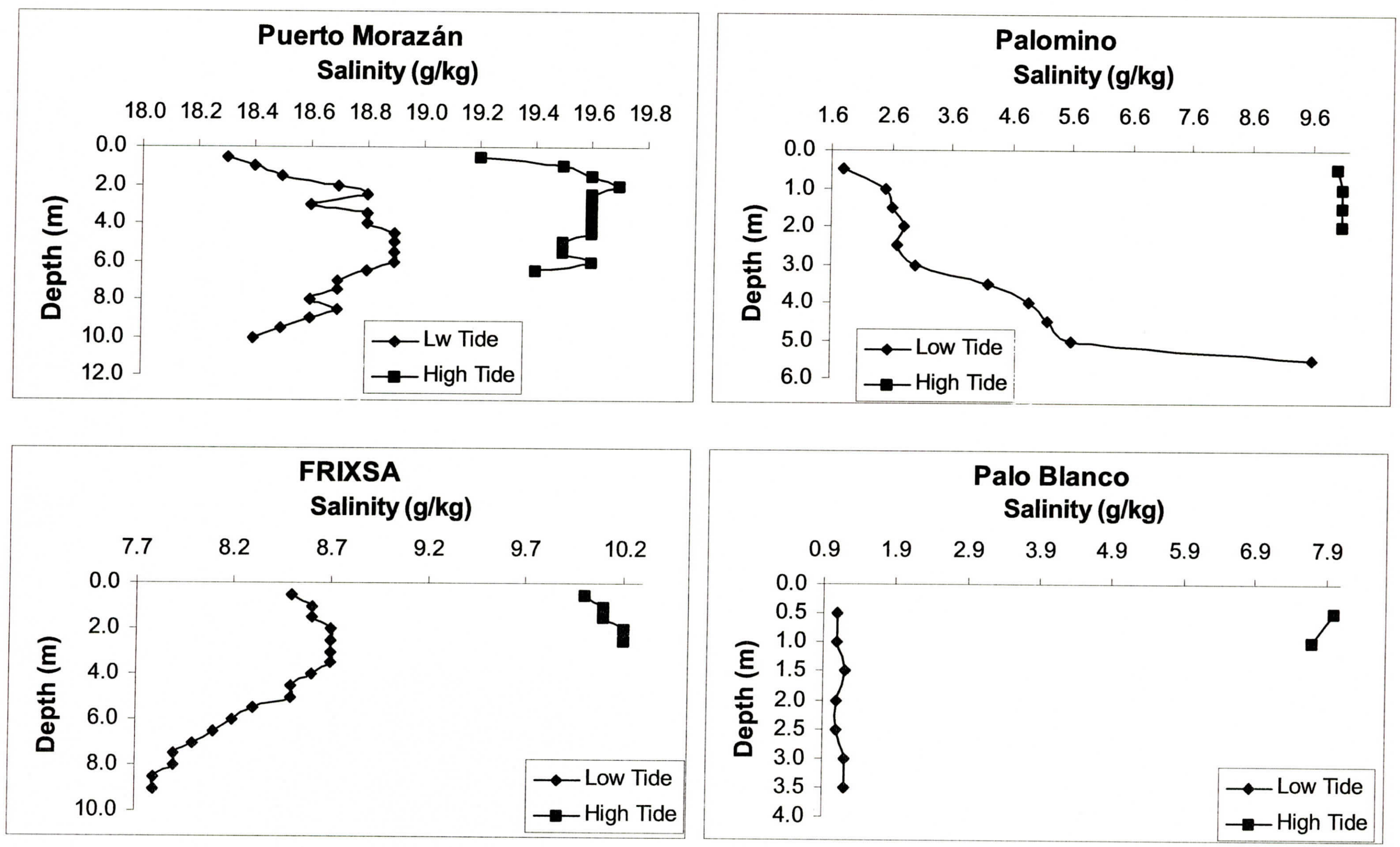


Figure 21 - continued. Salinity profiles at high and low tide on 25-26 June 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

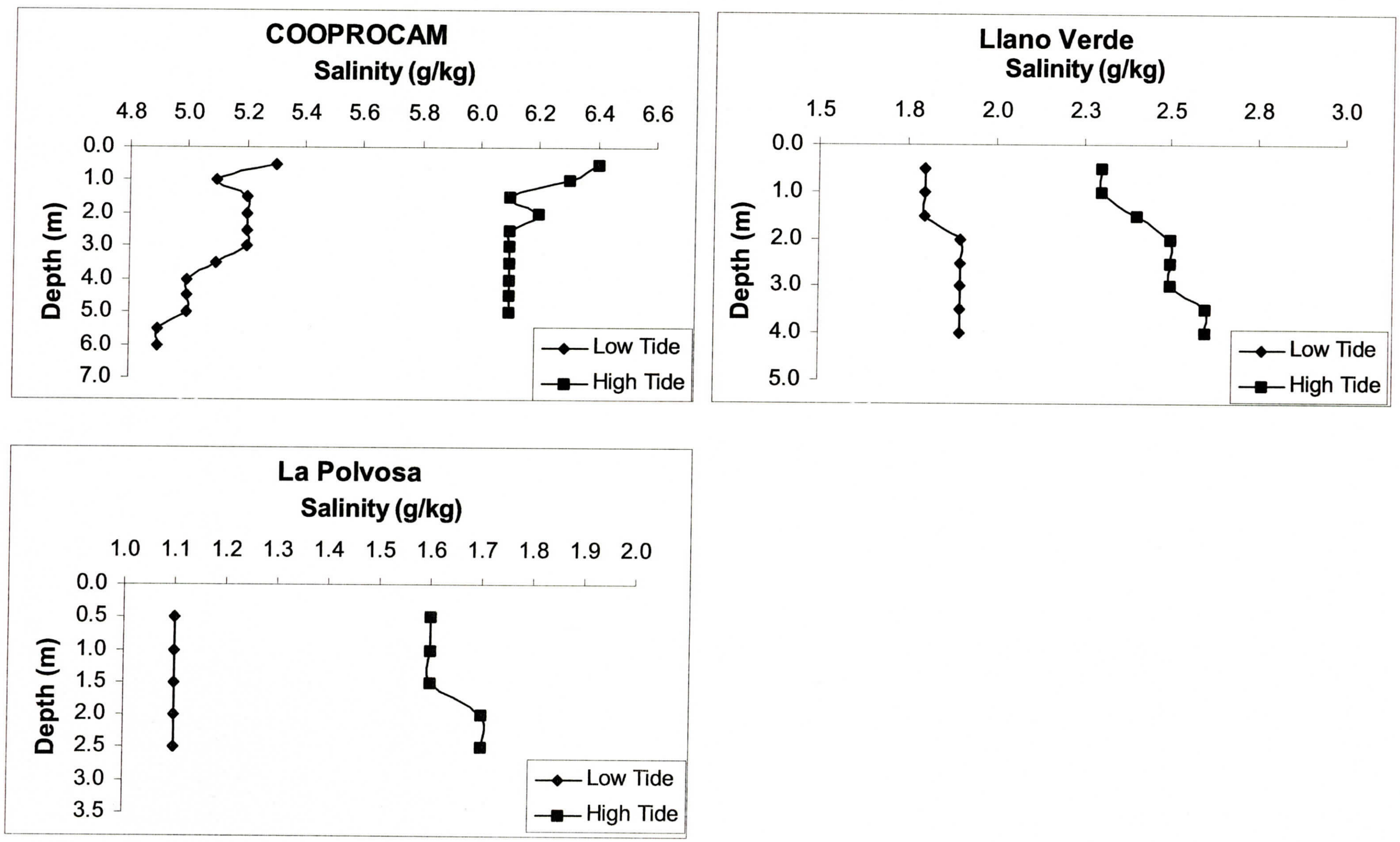


Figure 22. Dissolved oxygen profiles at high and low tide on 27-28 July 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

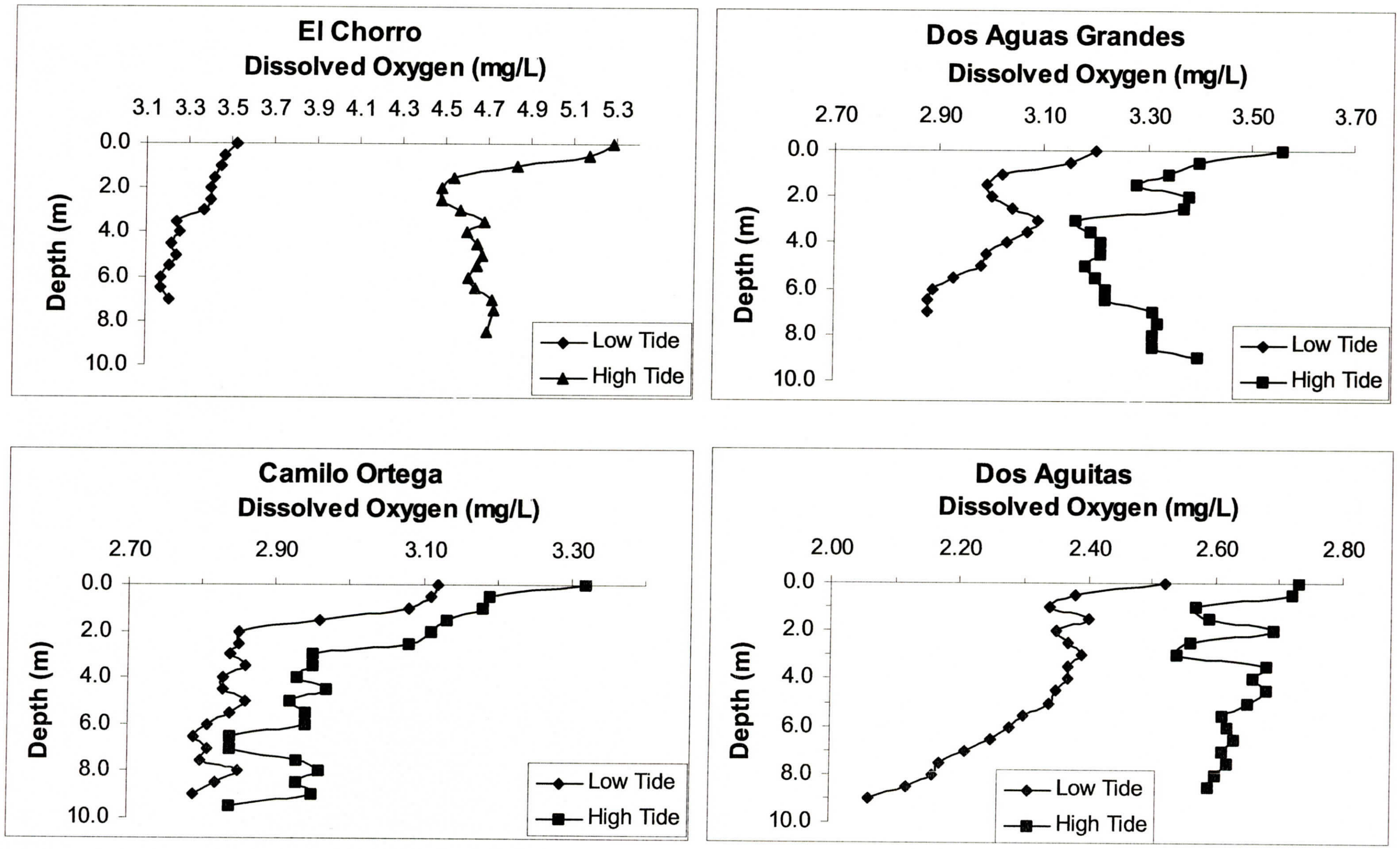


Figure 22 - continued. Dissolved oxygen profiles at high and low tide on 27-28 July 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

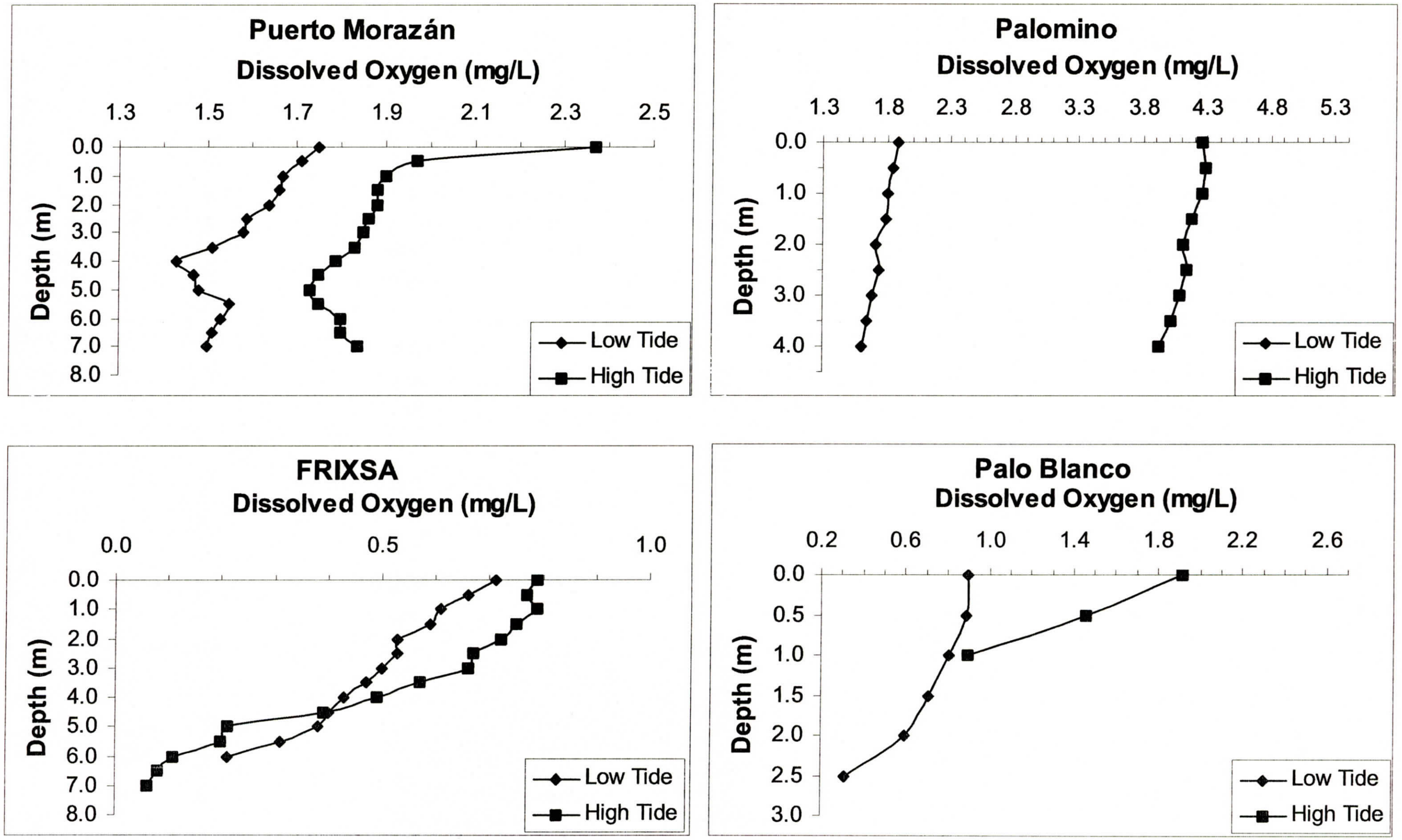


Figure 22 - continued. Dissolved oxygen profiles at high and low tide on 27-28 July 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

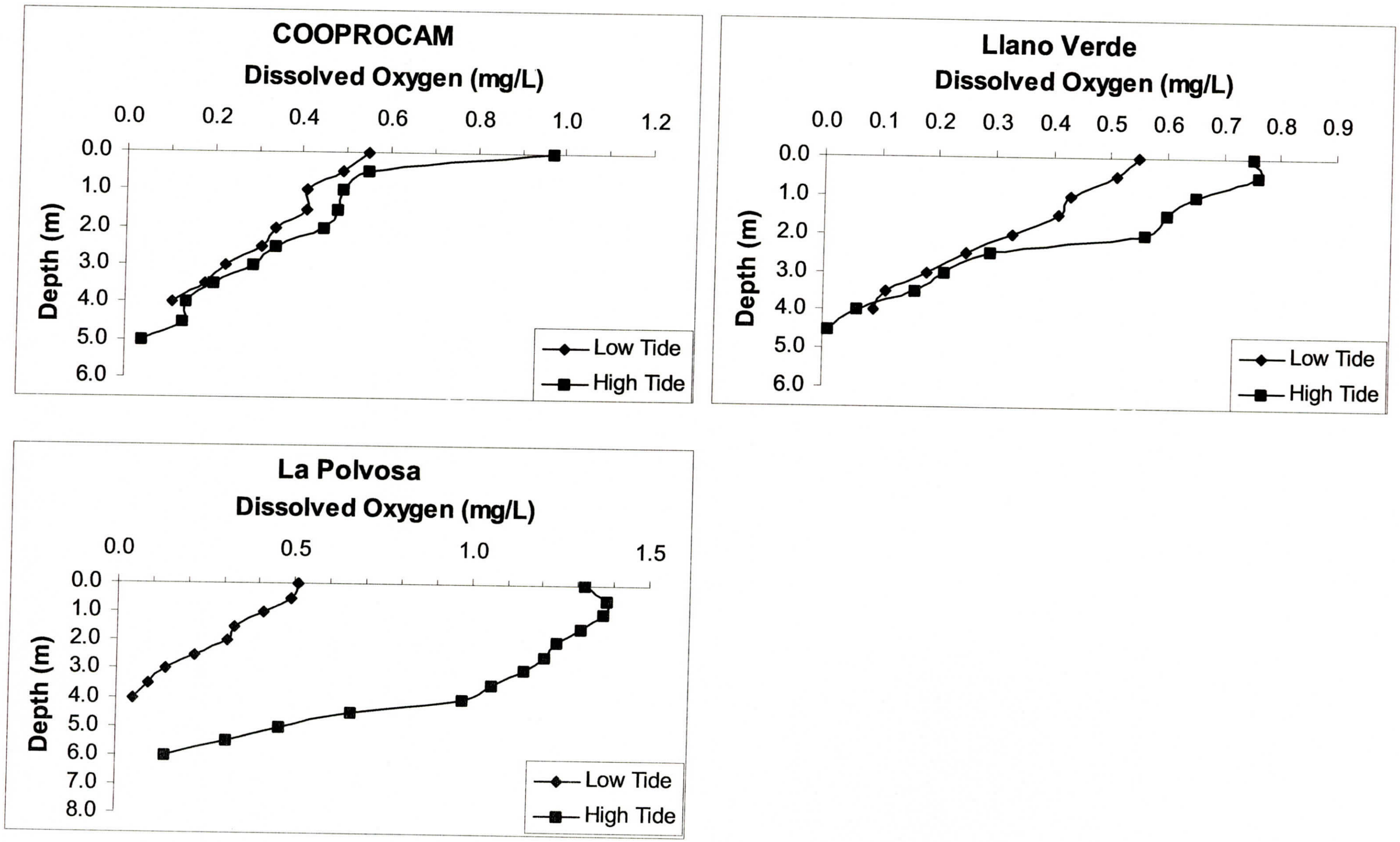


Figure 23. Salinity profiles at high and low tide on 27-28 July 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

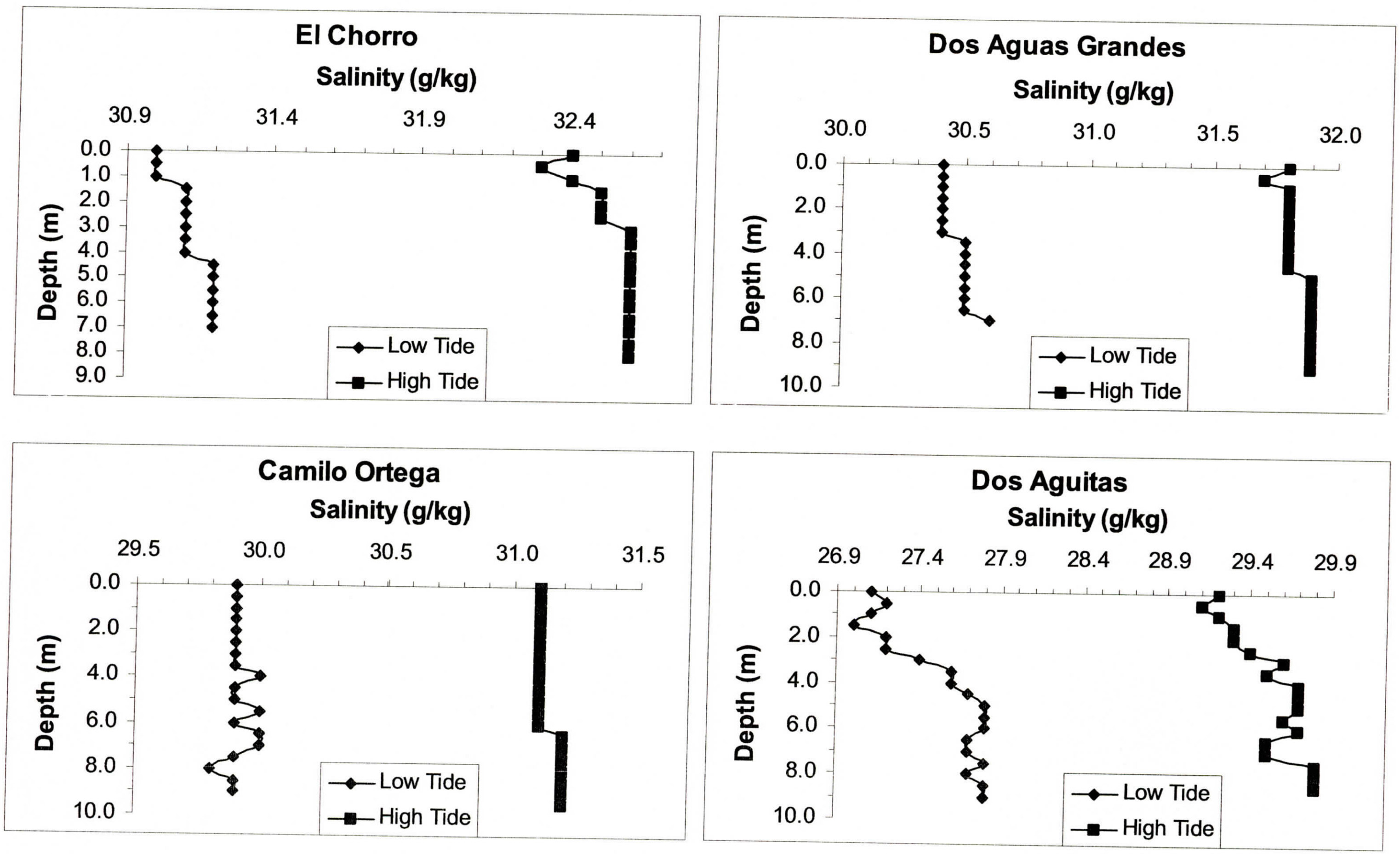


Figure 23 - continued. Salinity profiles at high and low tide on 27-28 July 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

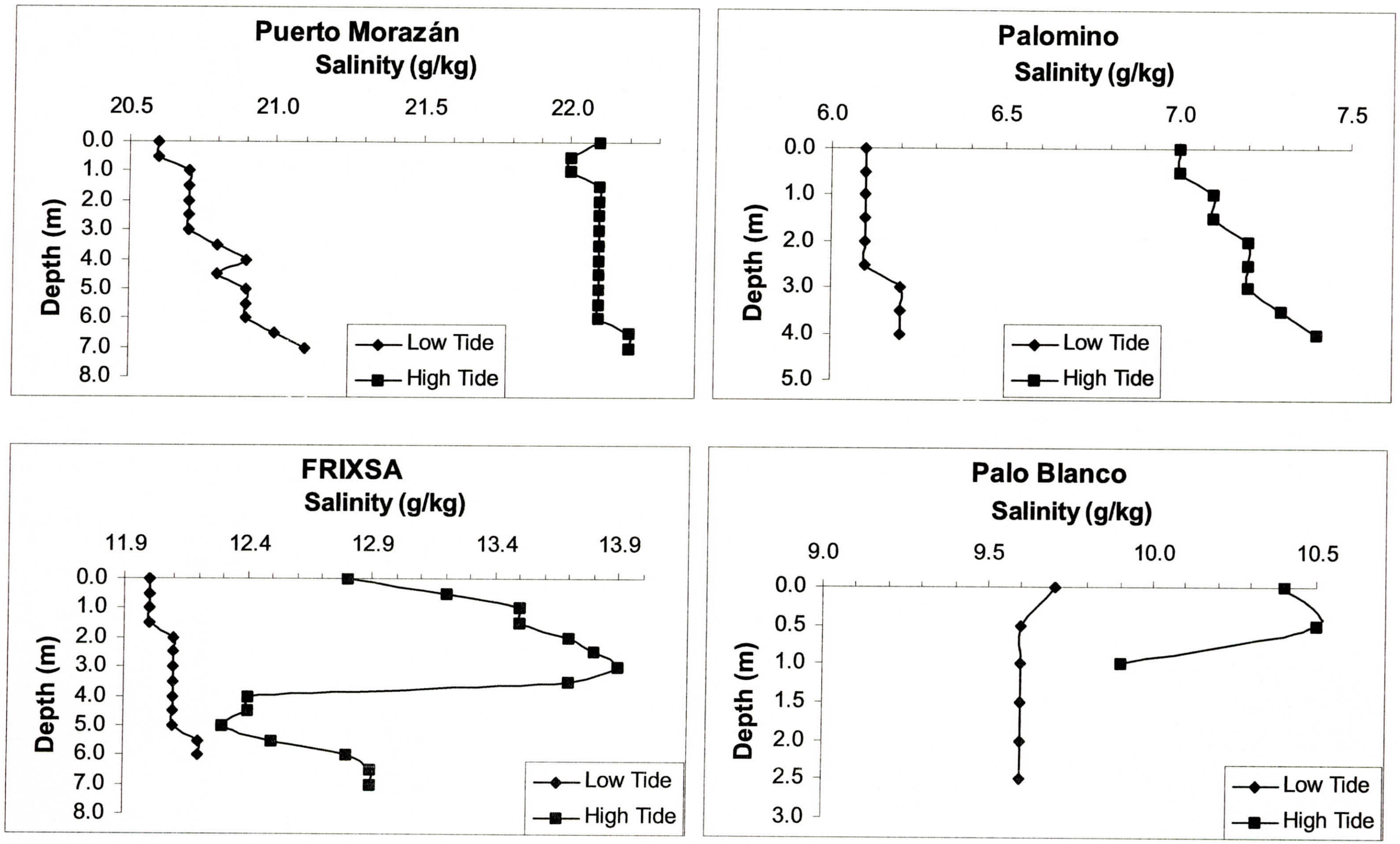
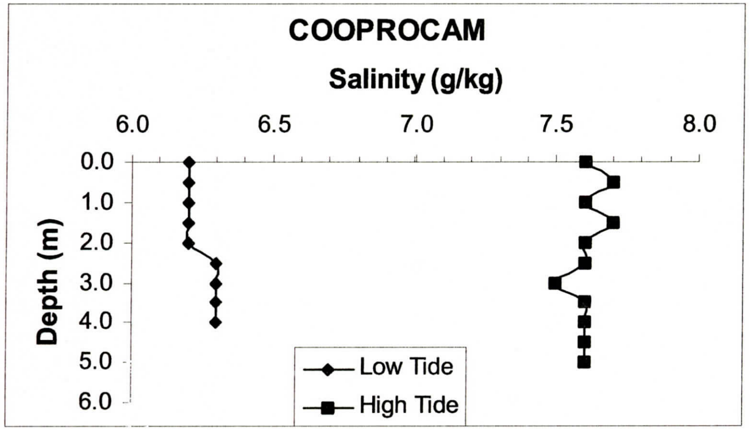
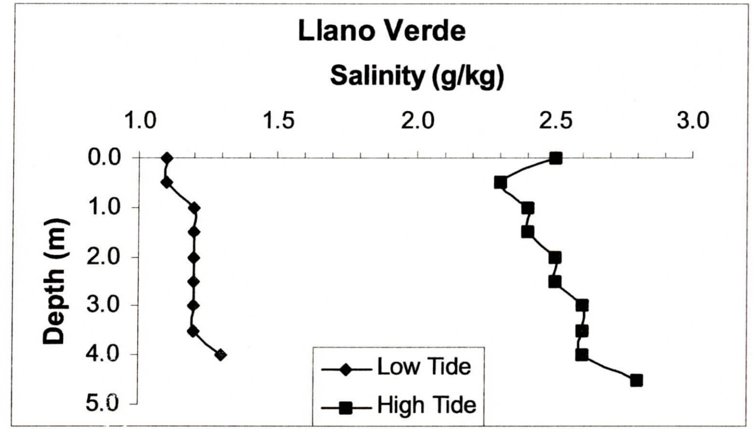


Figure 23 - continued. Salinity profiles at high and low tide on 27-28 July 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.





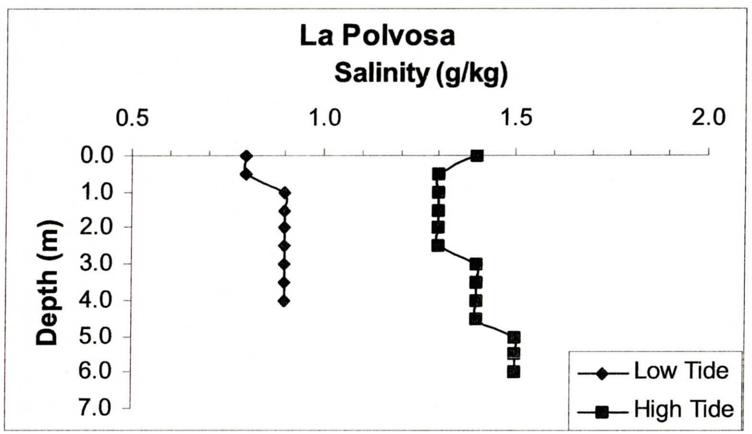


Figure 24. Dissolved oxygen profiles at high and low tide on 22-23 August 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

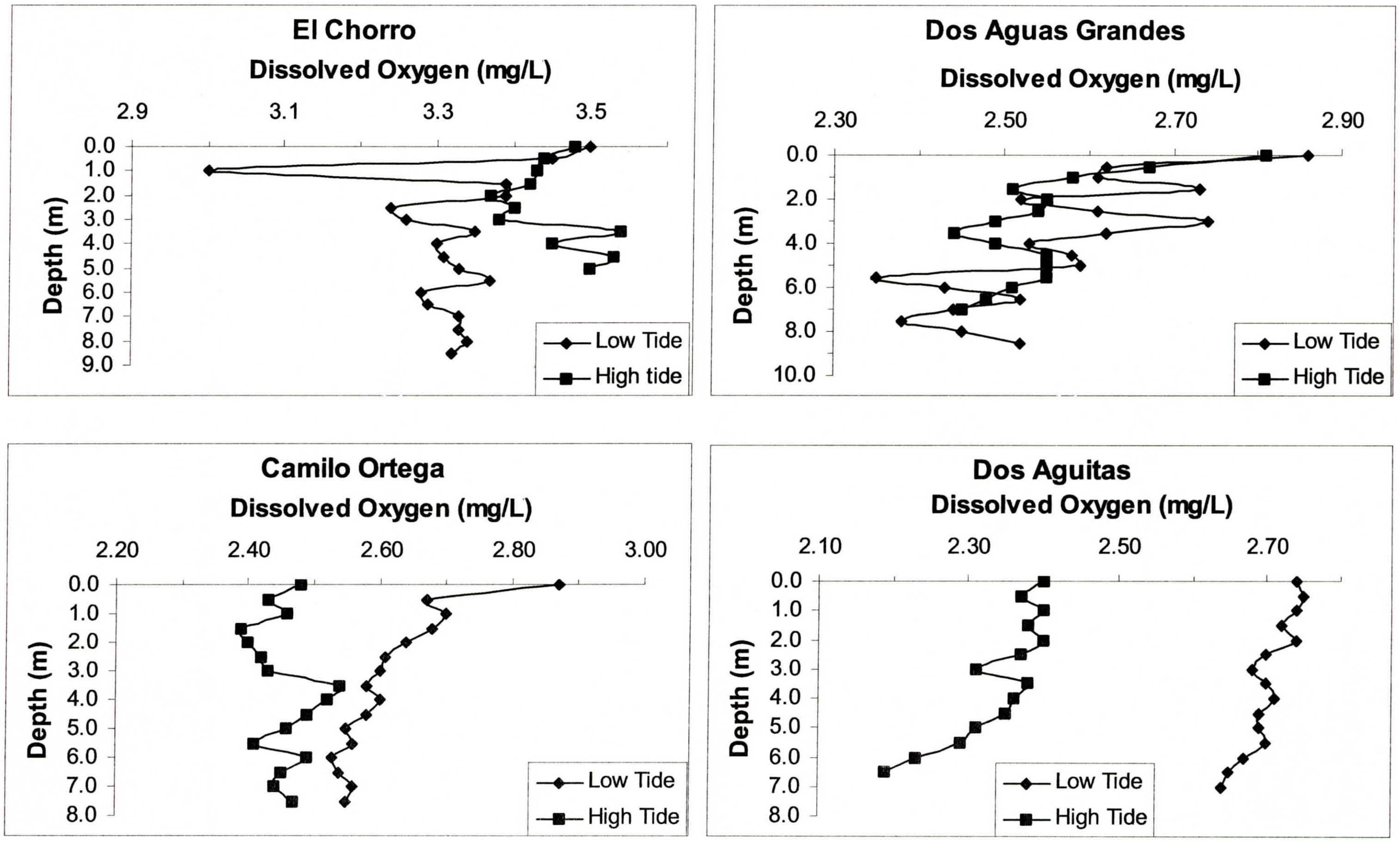


Figure 24 - continued. Dissolved oxygen profiles at high and low tide on 22-23 August 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

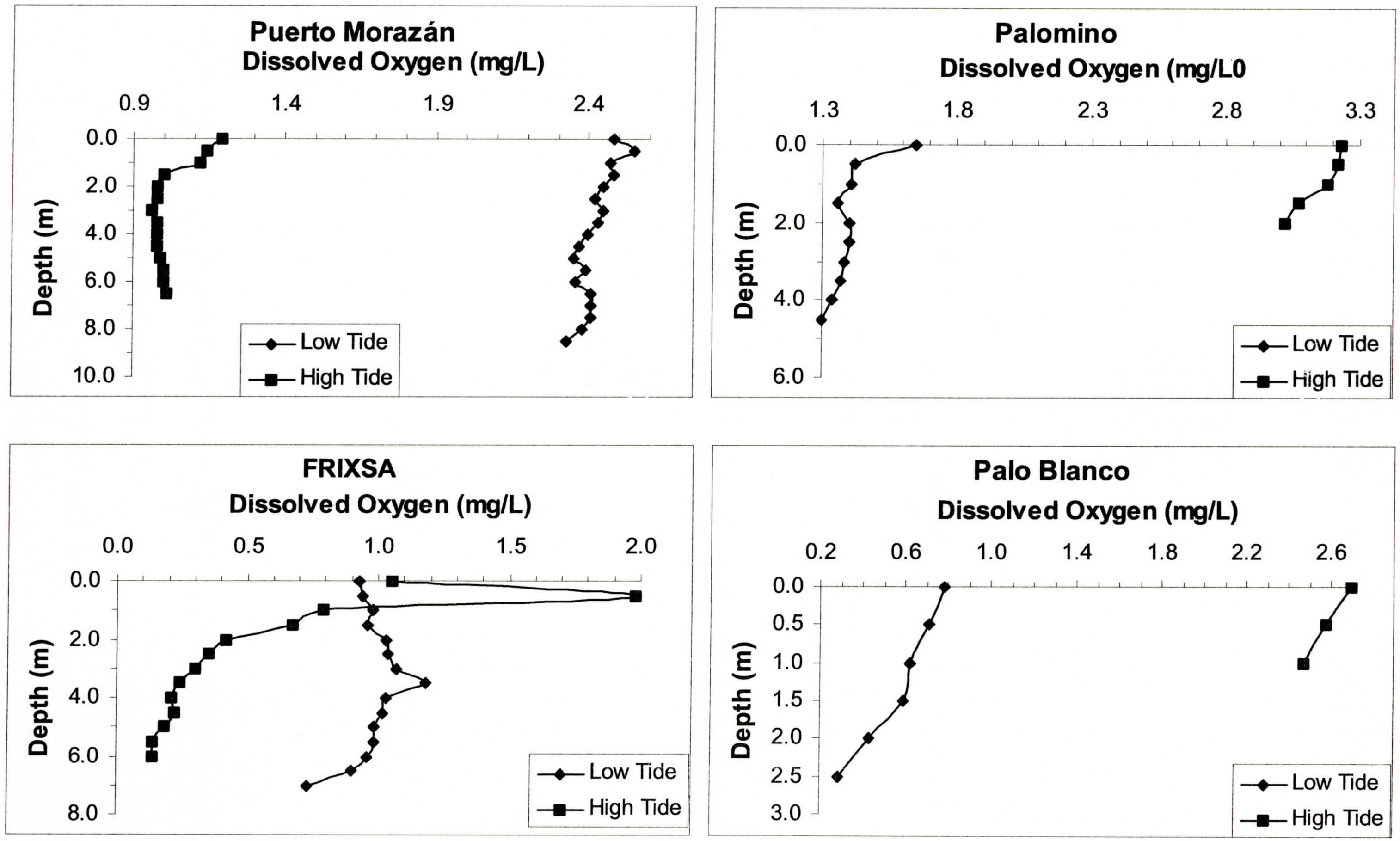
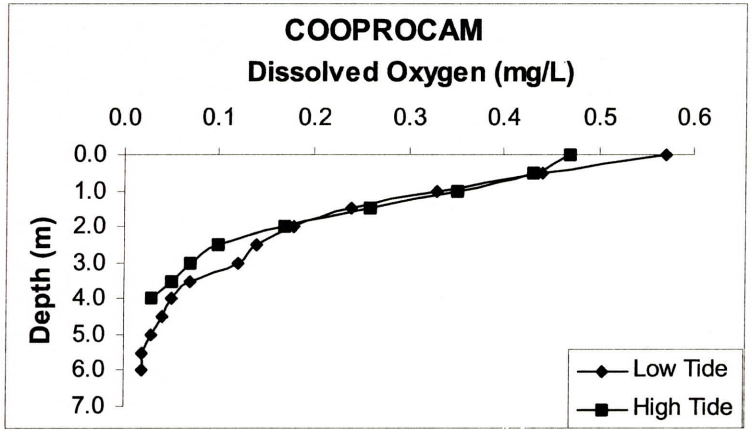
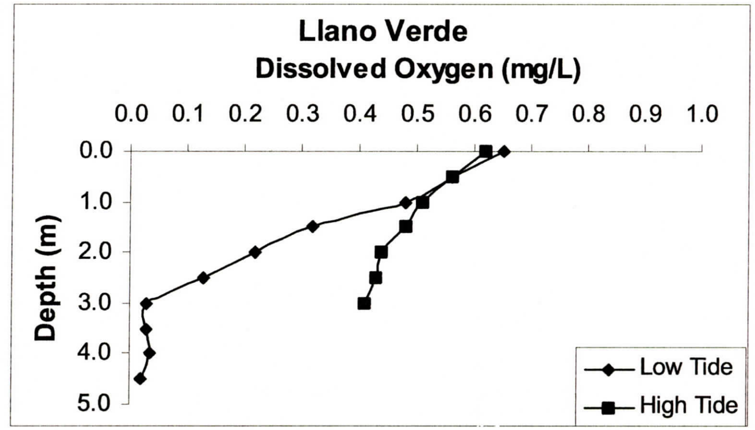


Figure 24 - continued. Dissolved oxygen profiles at high and low tide on 22-23 August 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.





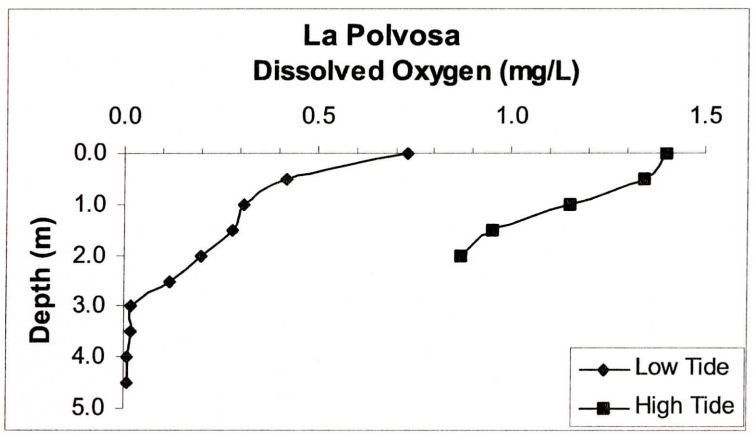


Figure 25. Salinity profiles at high and low tide on 22-23 August 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

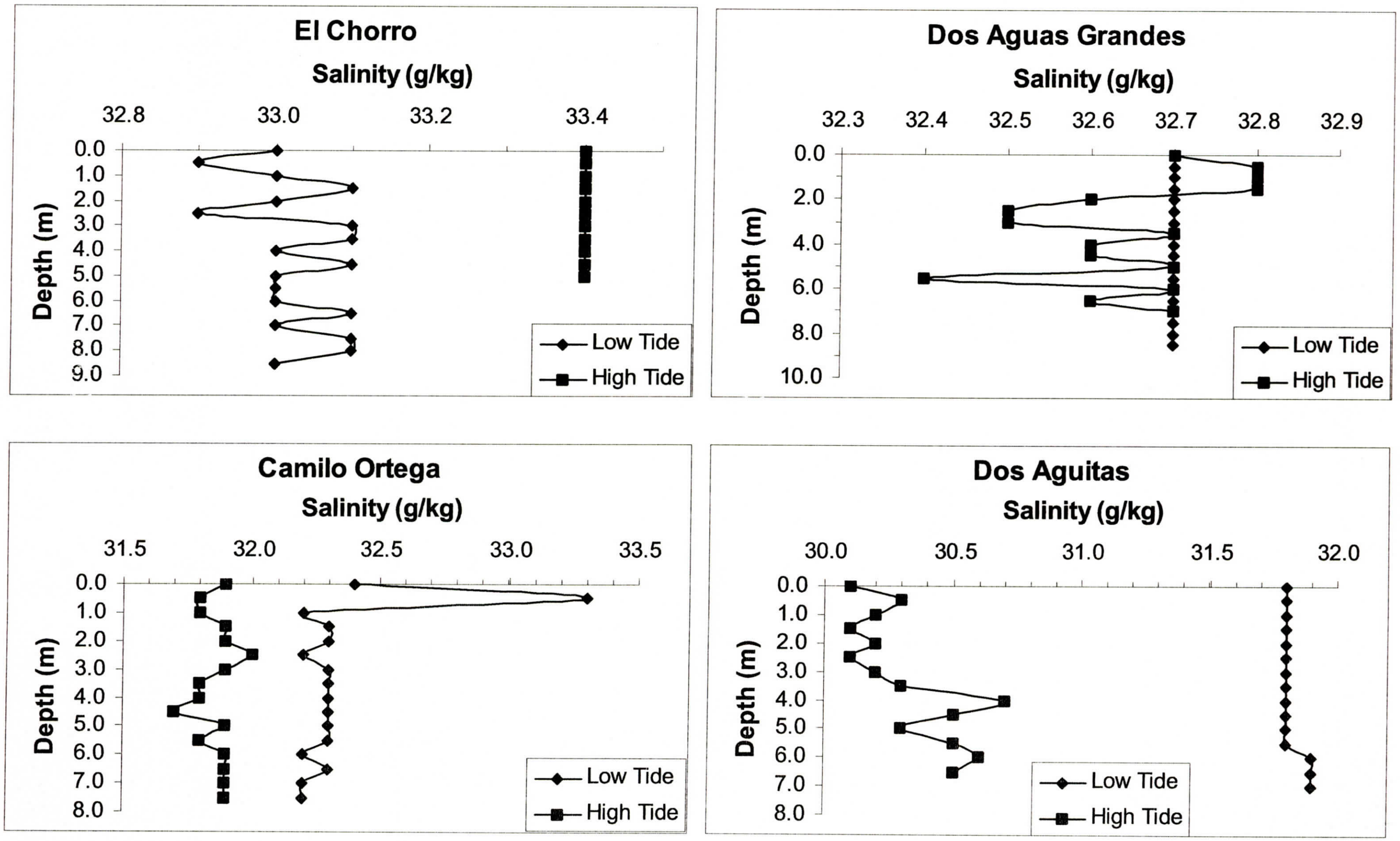


Figure 25 - continued. Salinity profiles at high and low tide on 22-23 August 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

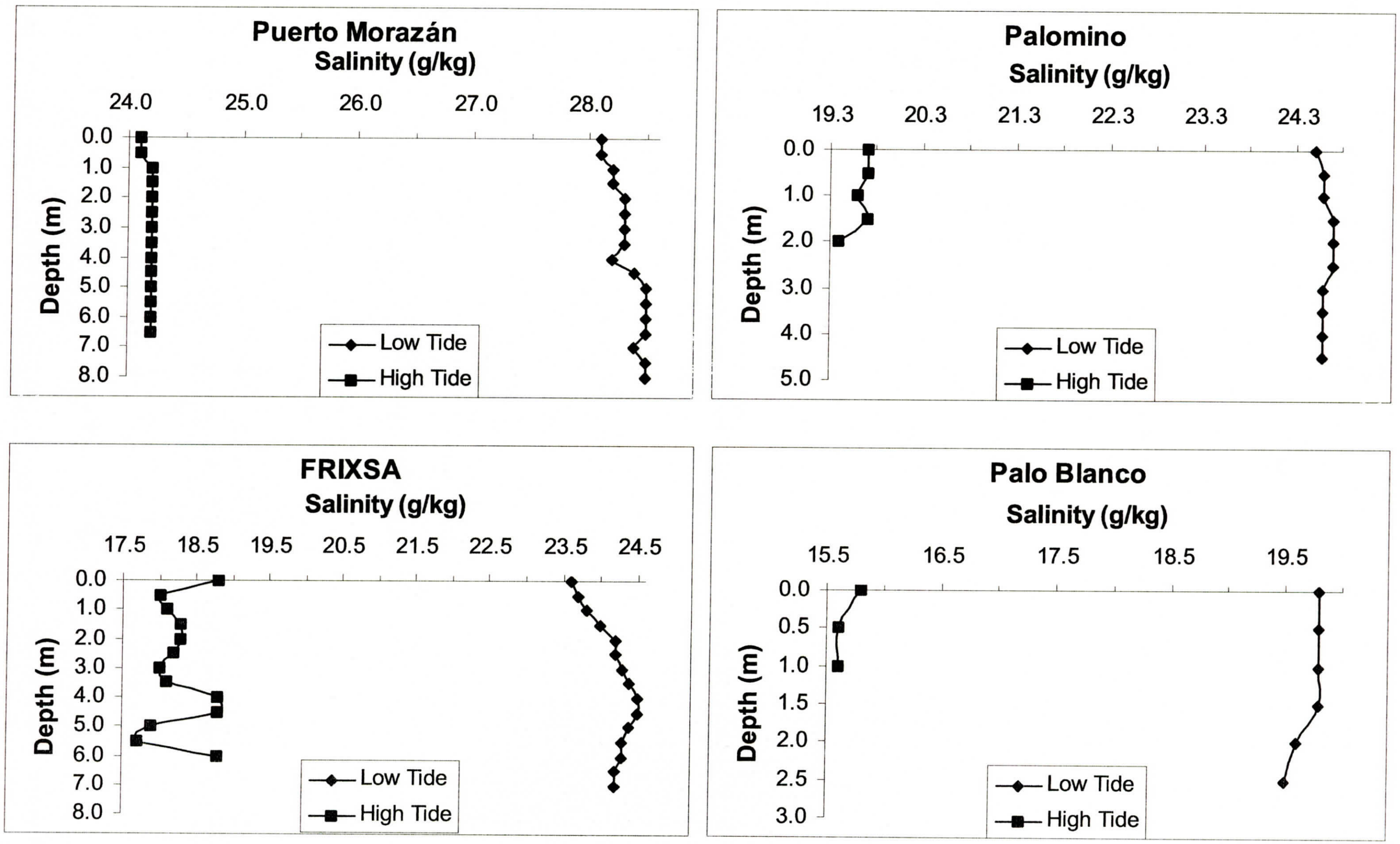


Figure 25 - continued. Salinity profiles at high and low tide on 22-23 August 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

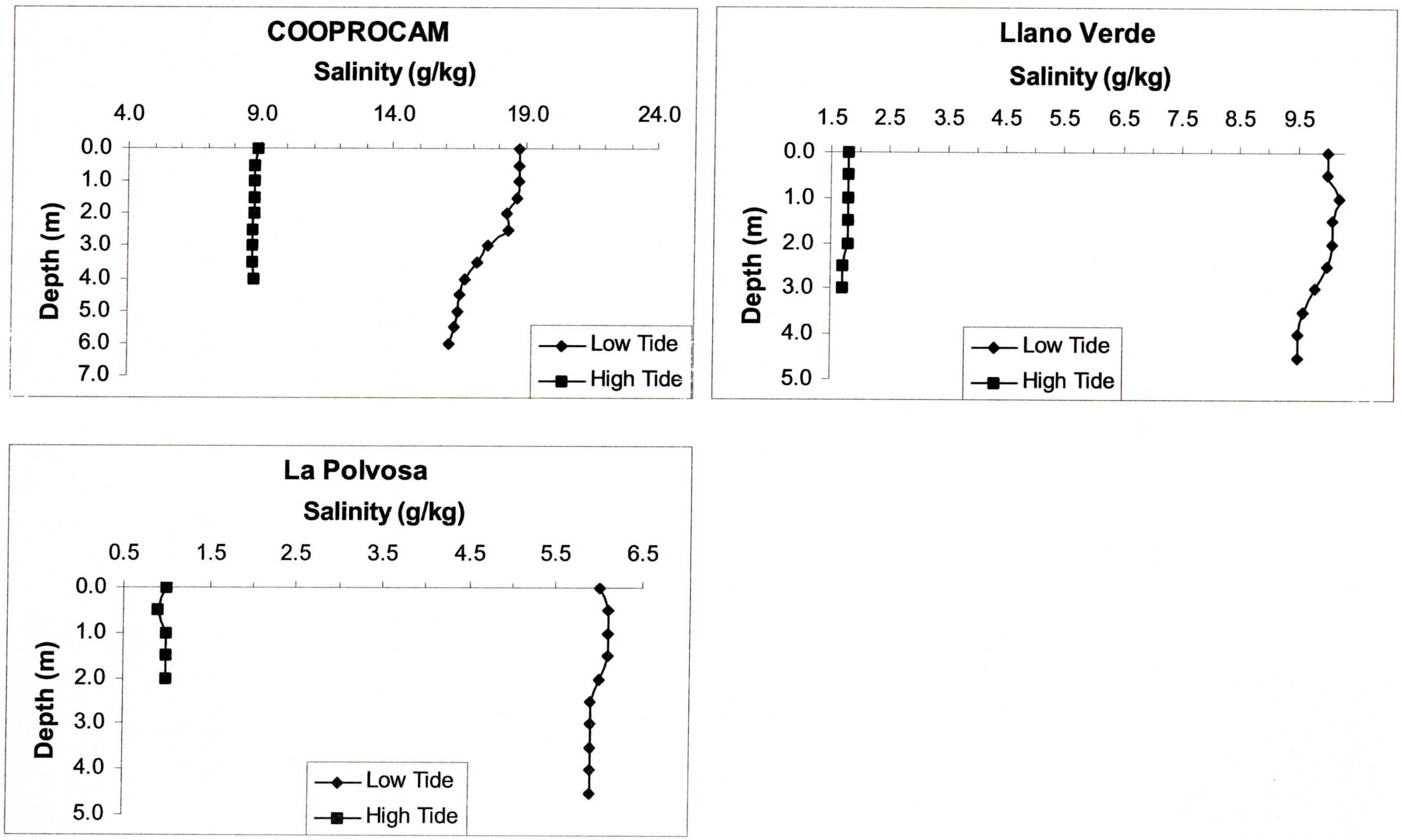


Figure 26. Dissolved oxygen profiles at high and low tide on 19-20 September 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

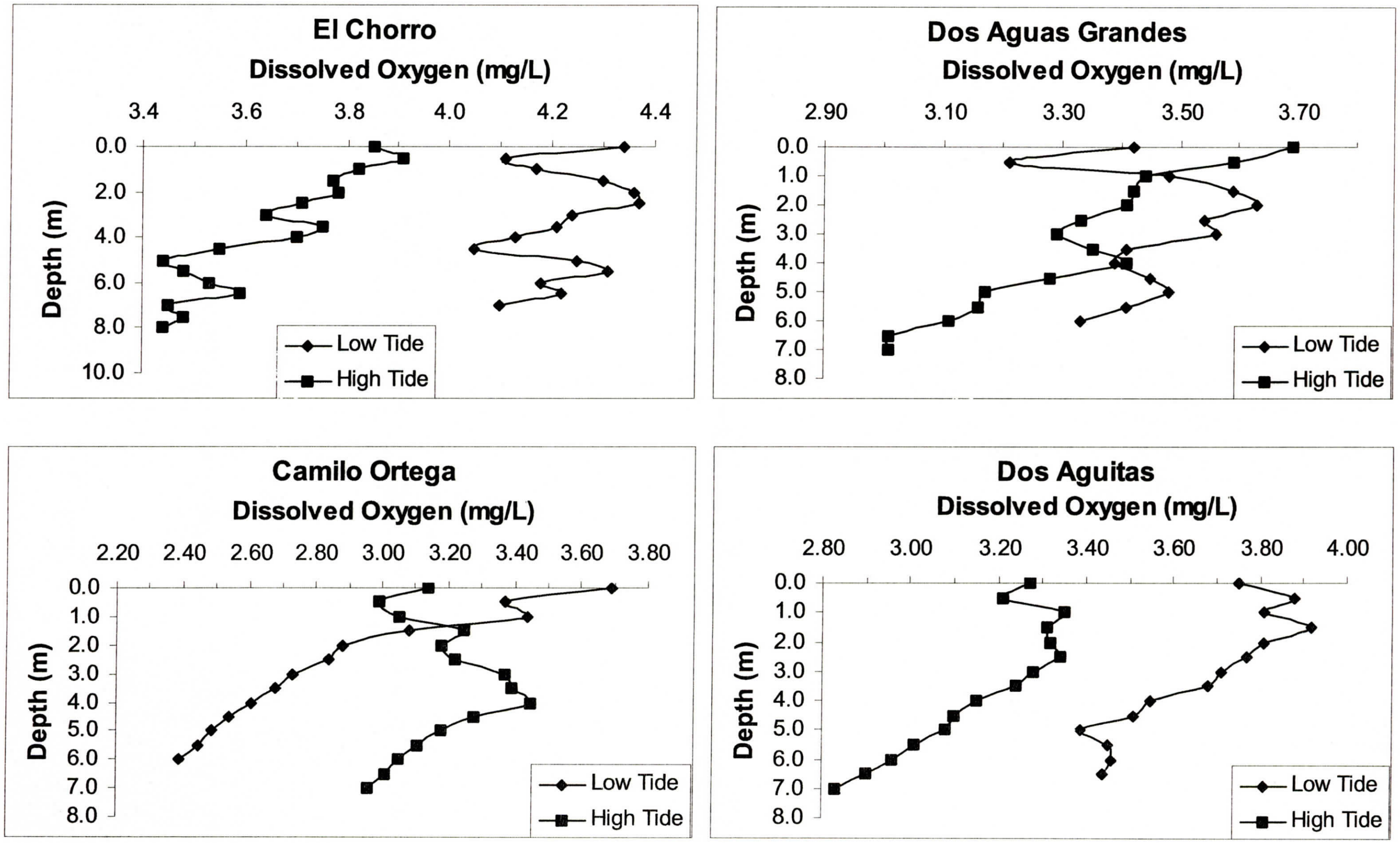


Figure 26 - continued. Dissolved oxygen profiles at high and low tide on 19-20 September 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

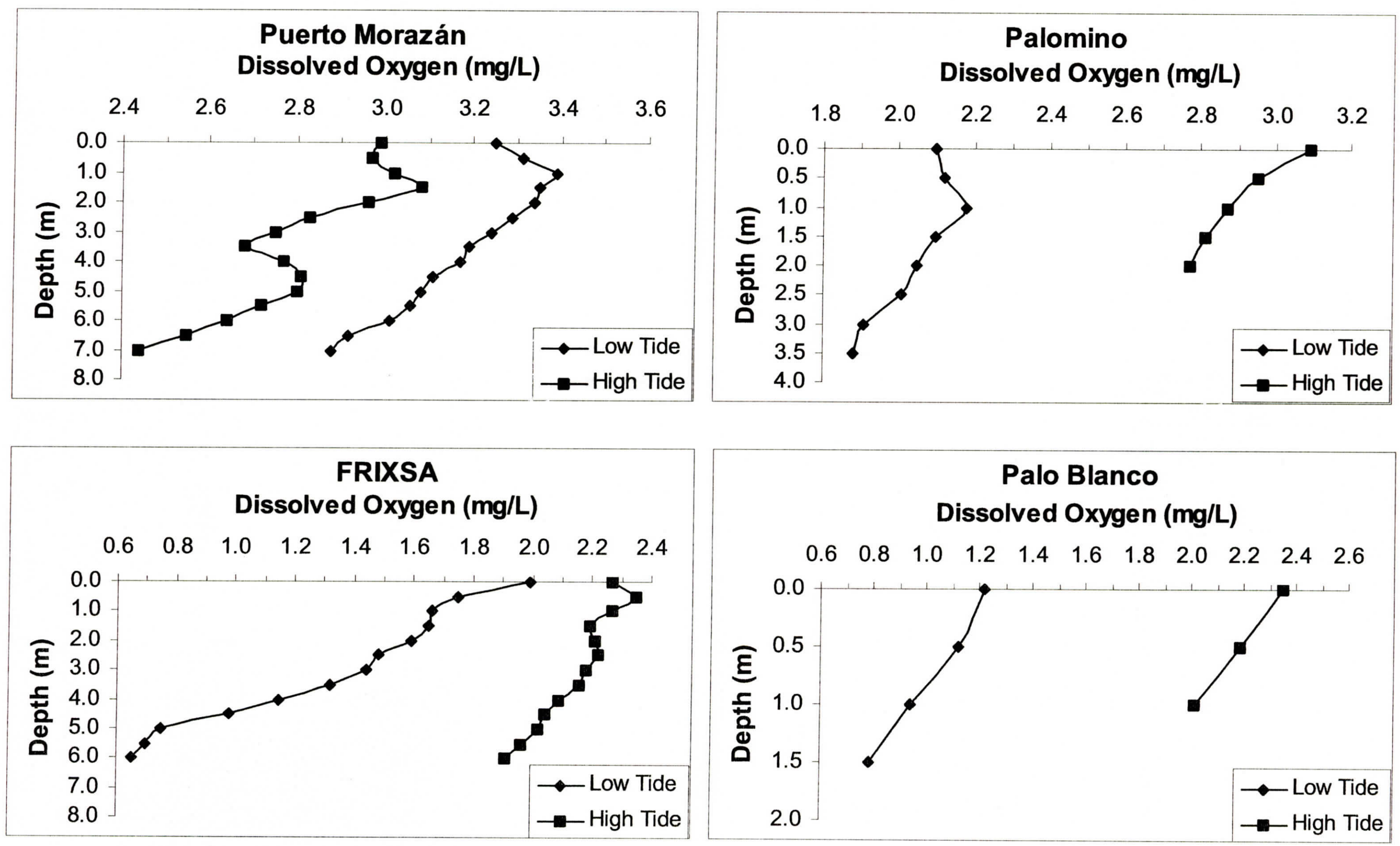
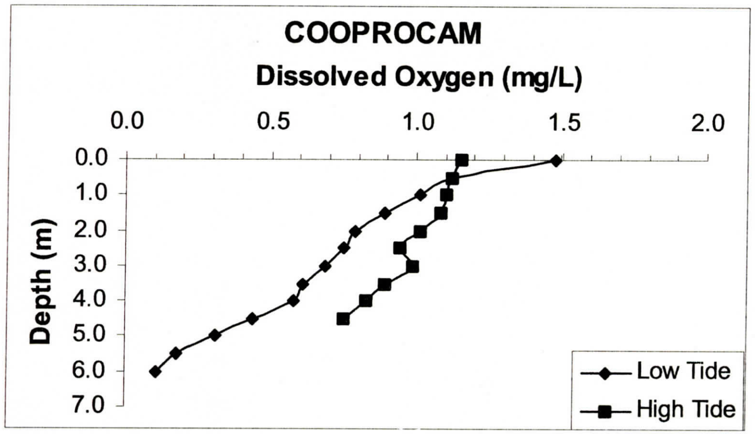
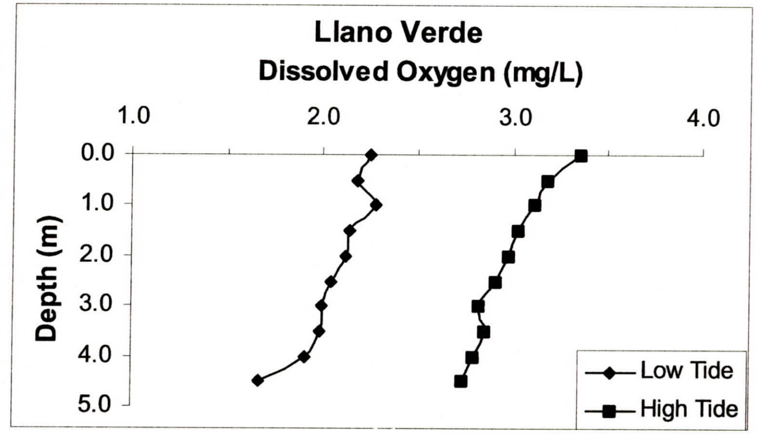


Figure 26 - continued. Dissolved oxygen profiles at high and low tide on 19-20 September 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.





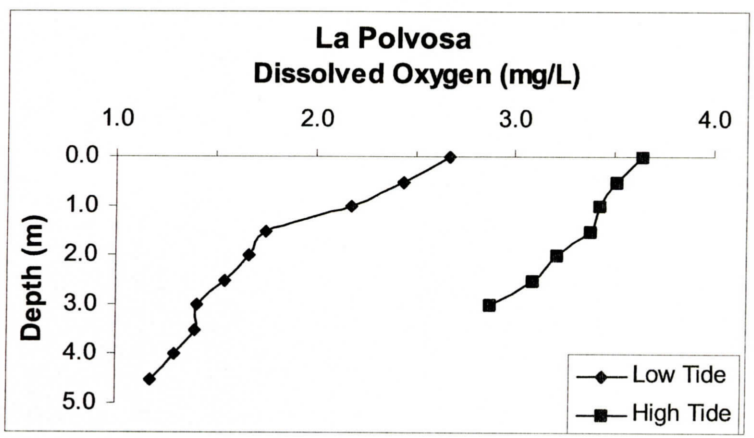


Figure 27. Salinity profiles at high and low tide on 19-20 September 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

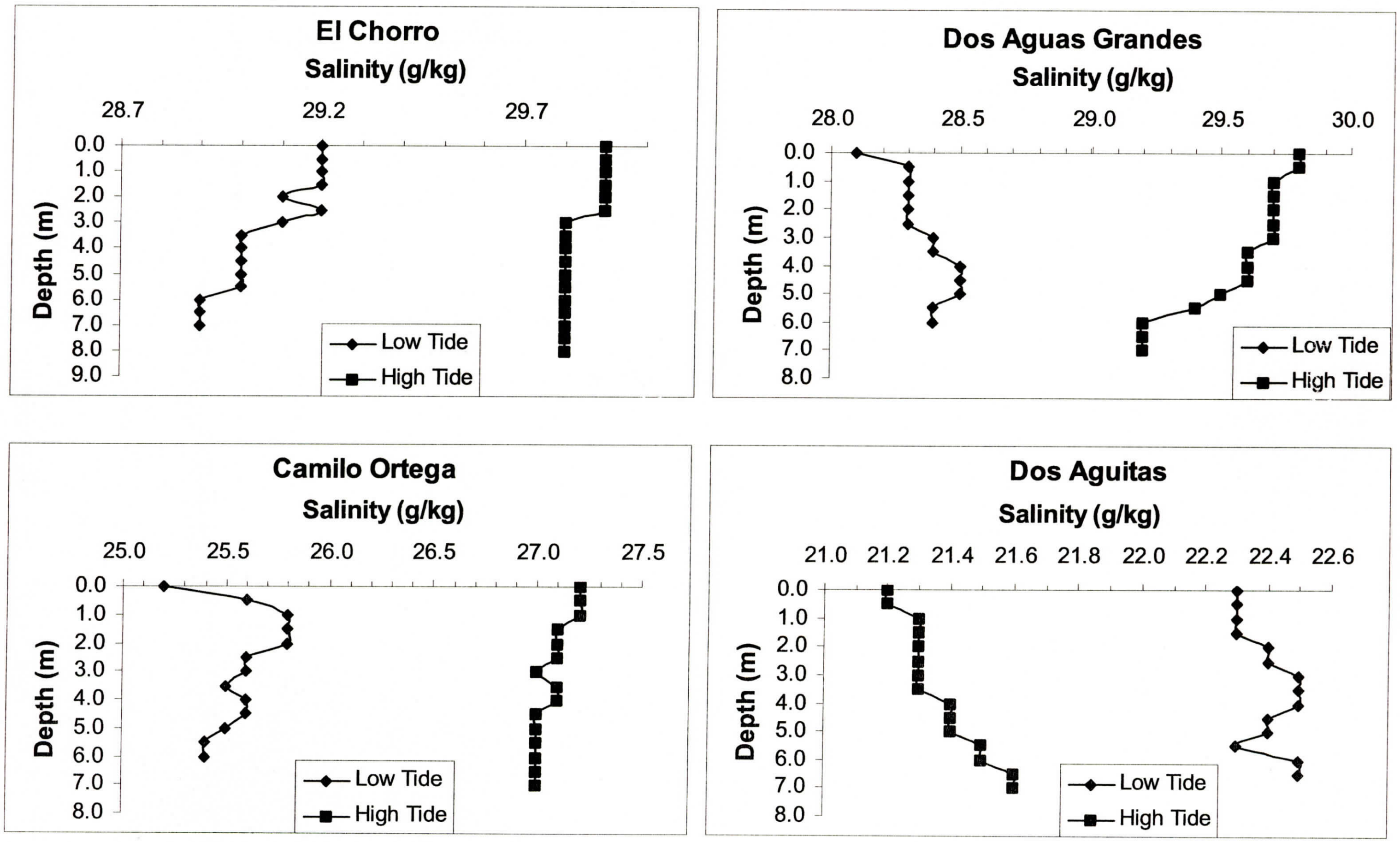


Figure 27 - continued. Salinity profiles at high and low tide on 19-20 September 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

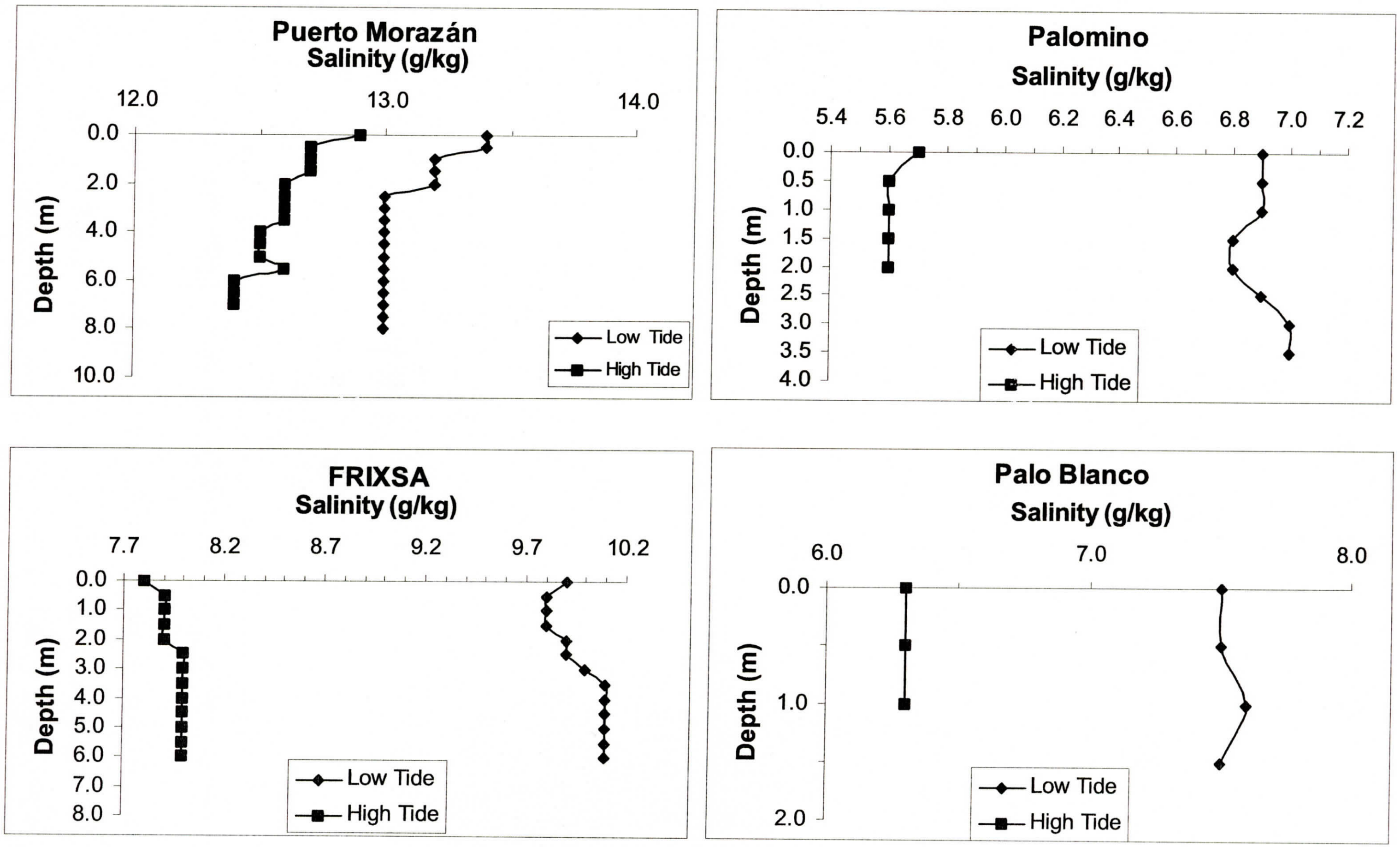
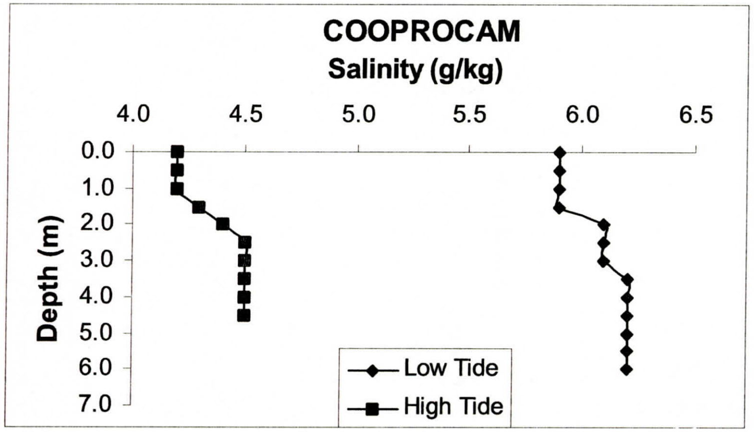
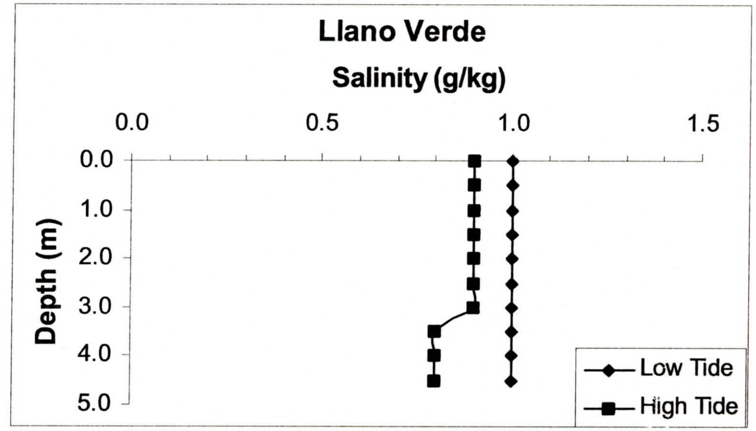


Figure 27 - continued. Salinity profiles at high and low tide on 19-20 September 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.





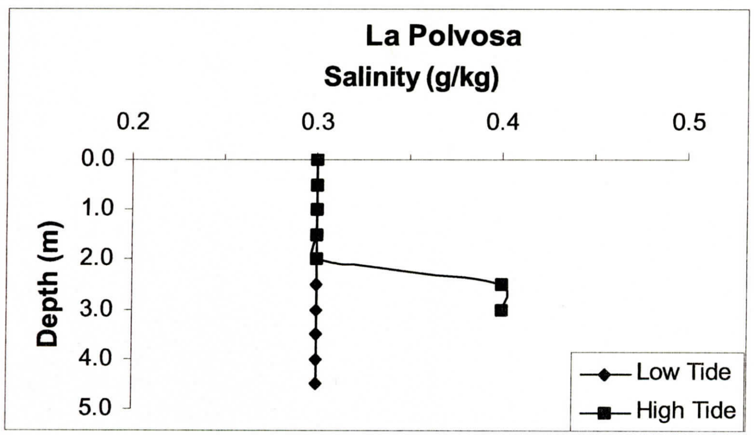


Figure 28. Dissolved oxygen profiles at high and low tide on 17-18 October 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

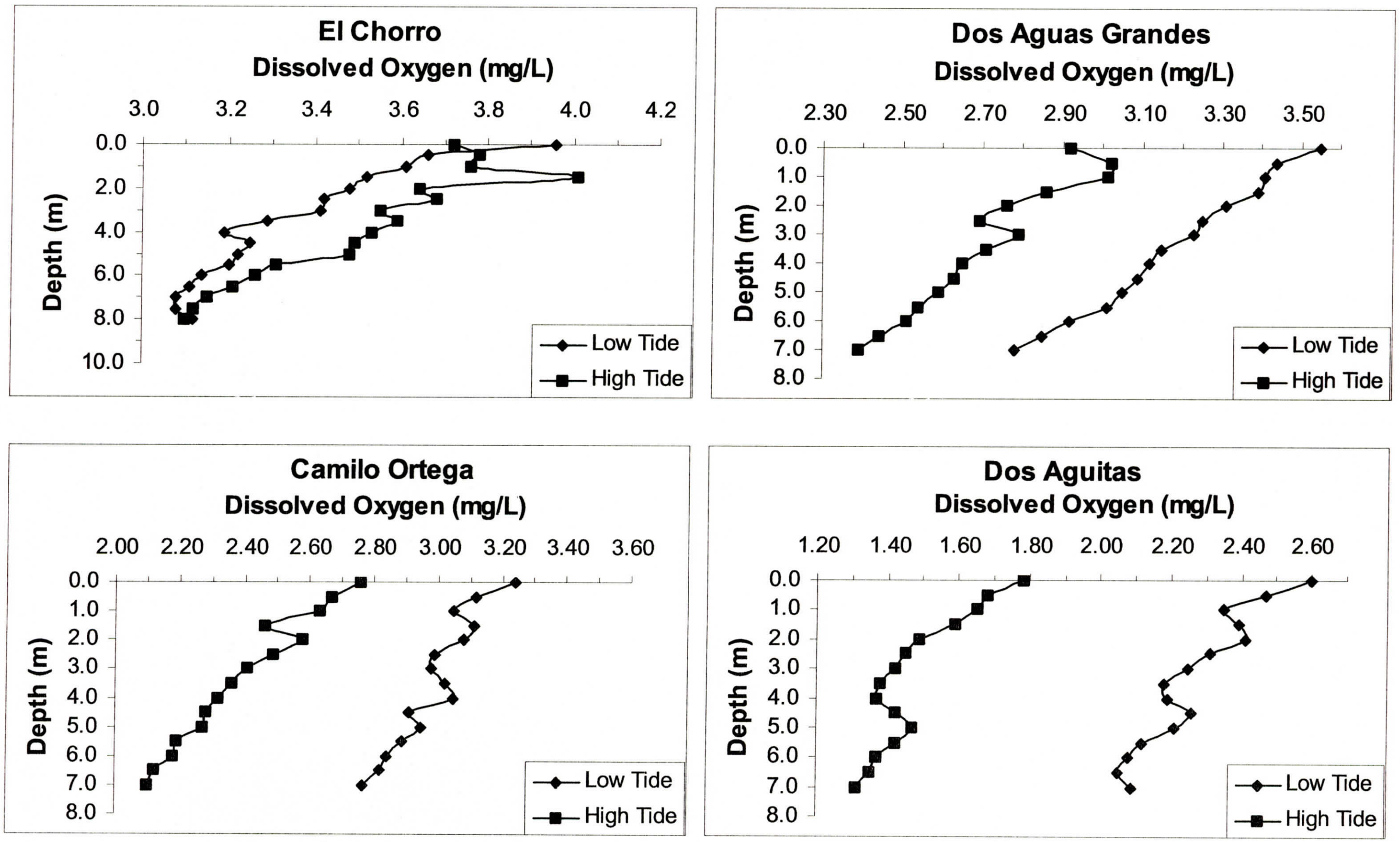


Figure 28 - continued. Dissolved oxygen profiles at high and low tide on 17-18 October 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

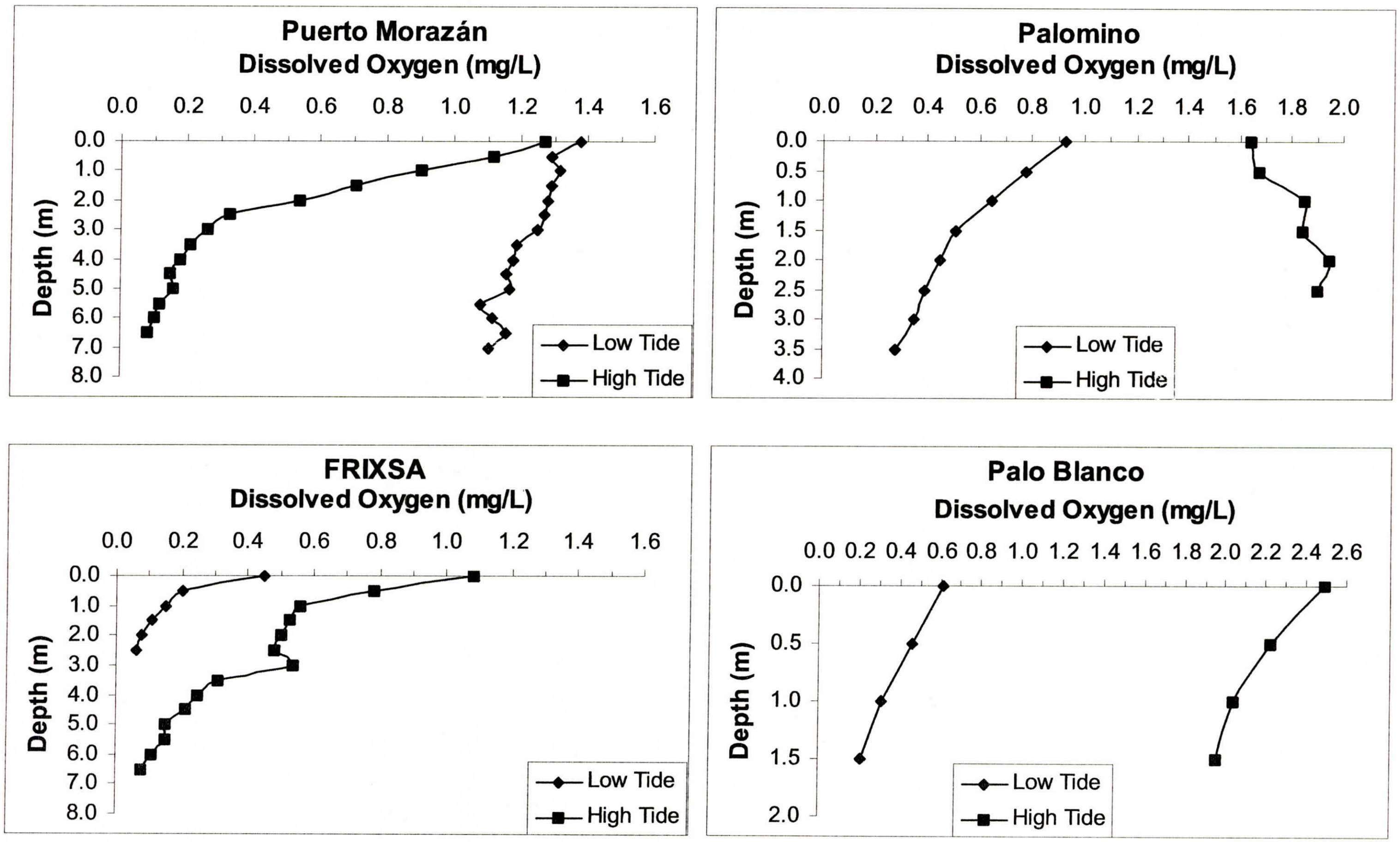
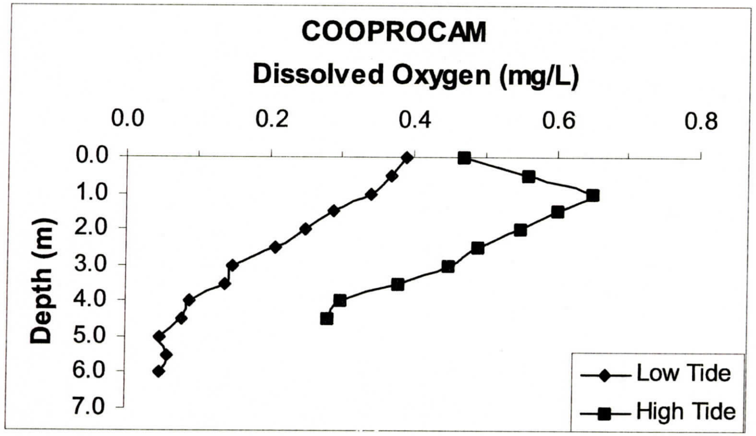
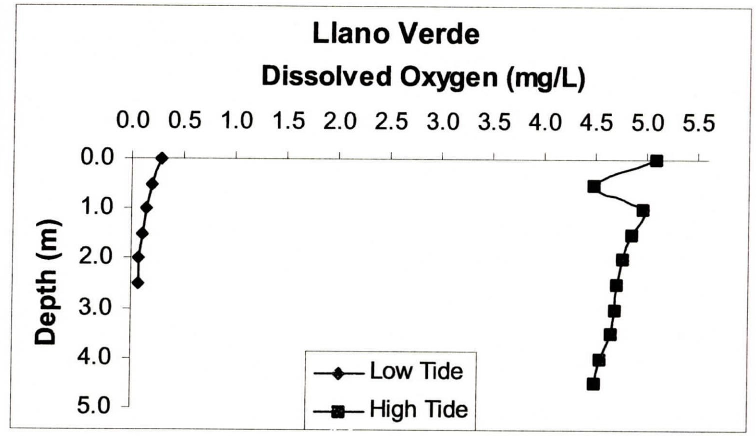


Figure 28 - continued. Dissolved oxygen profiles at high and low tide on 17-18 October 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.





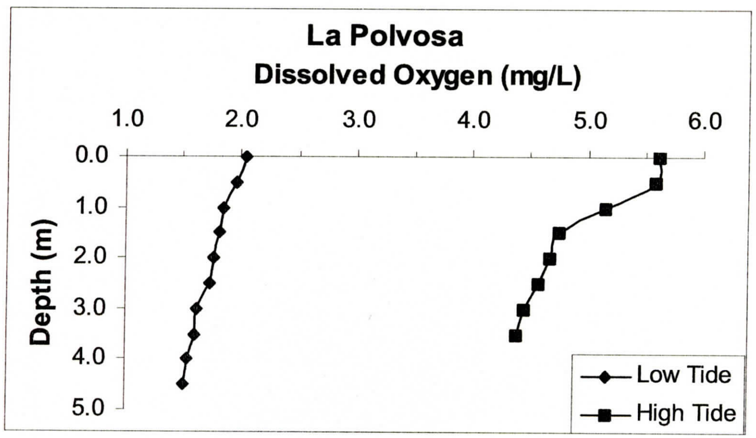


Figure 29. Salinity profiles at high and low tide on 17-18 October 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

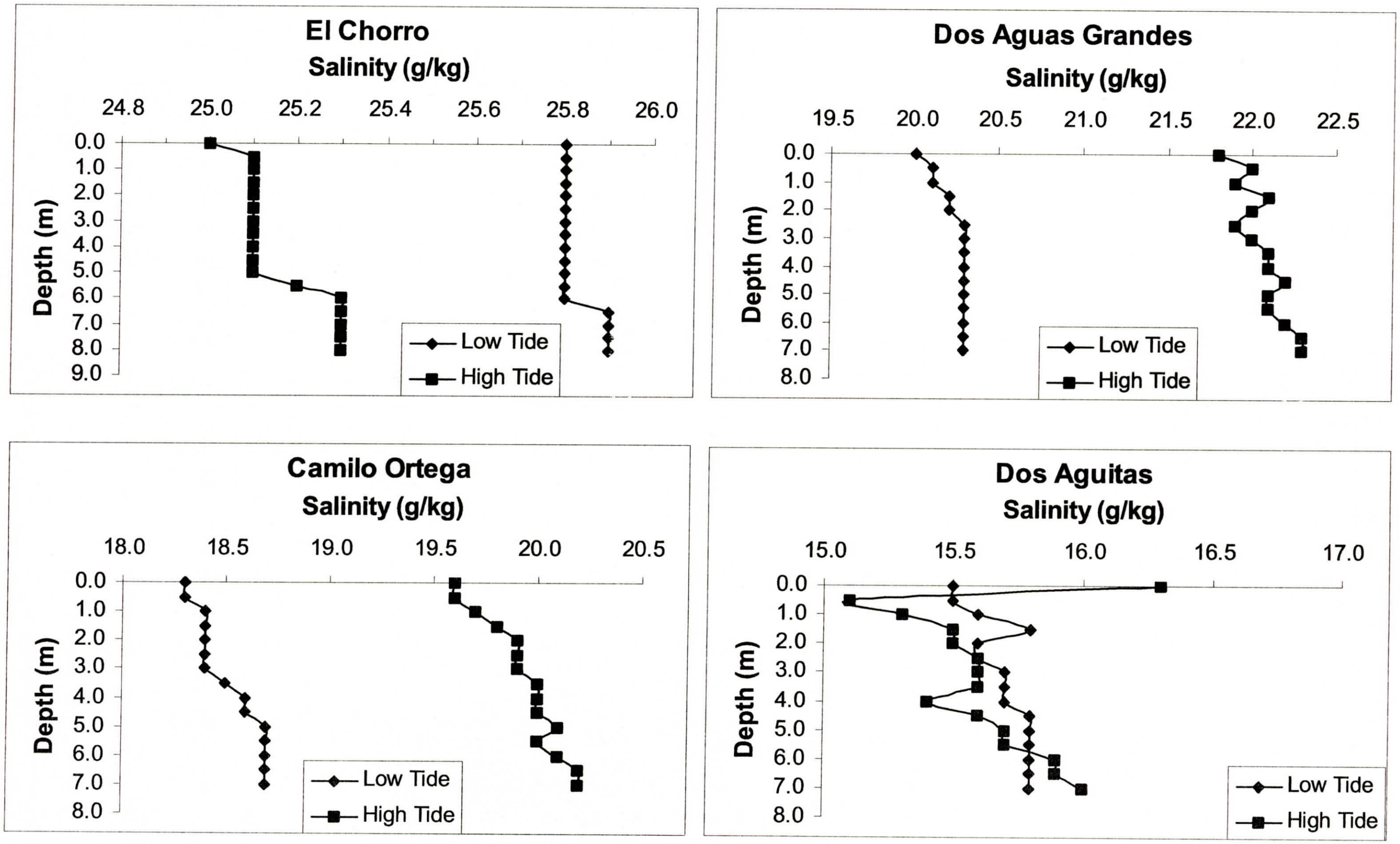


Figure 29 - continued. Salinity profiles at high and low tide on 17-18 October 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

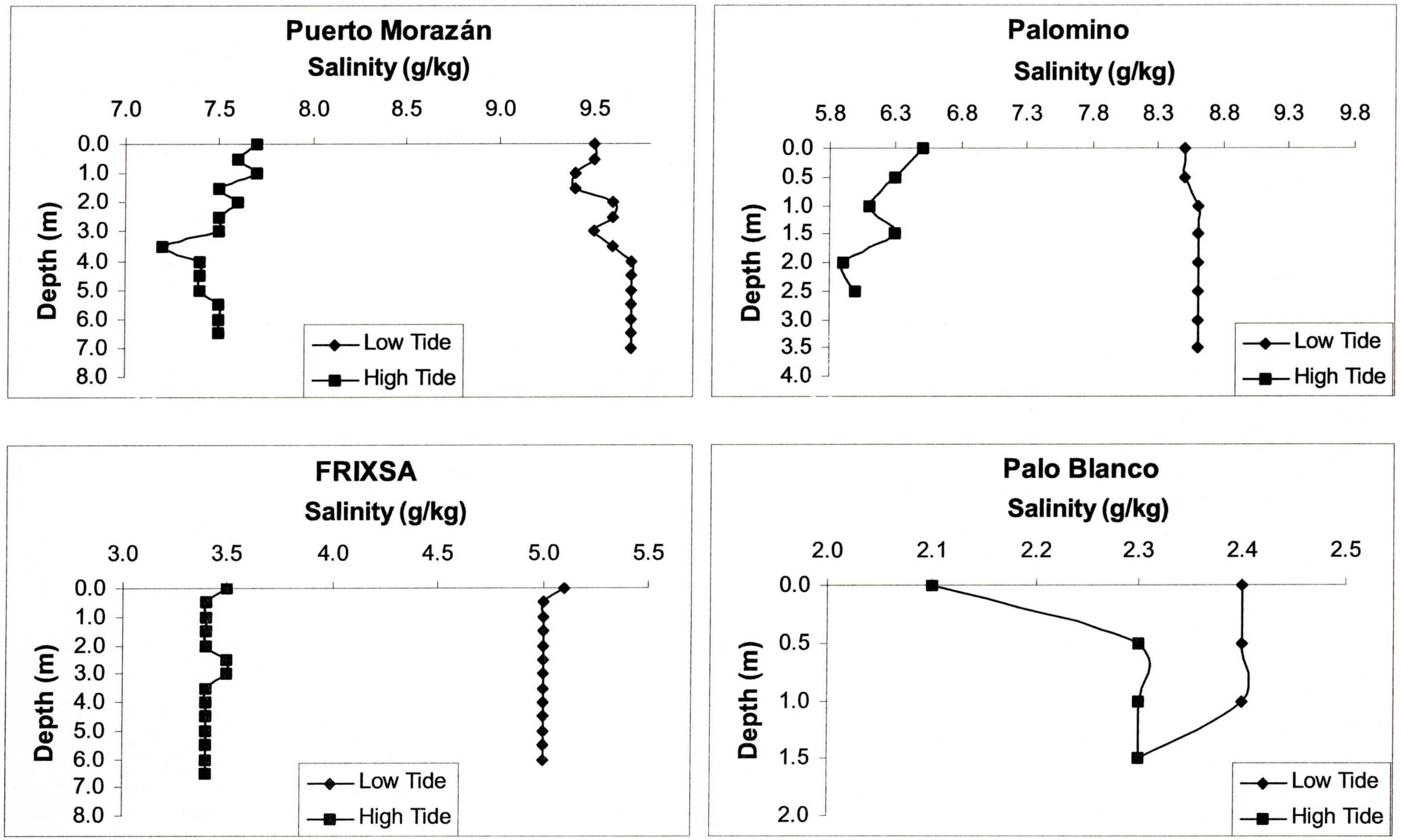
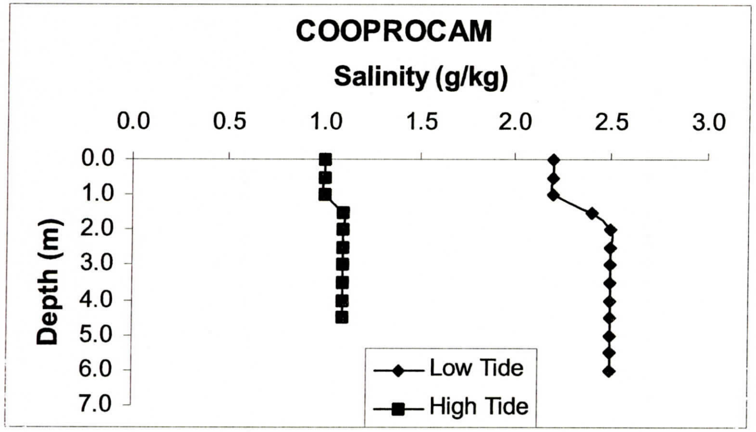
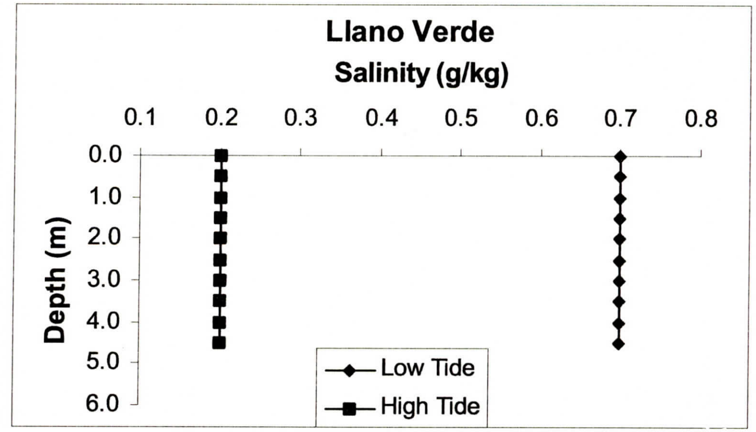


Figure 29 - continued. Salinity profiles at high and low tide on 17-18 October 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.





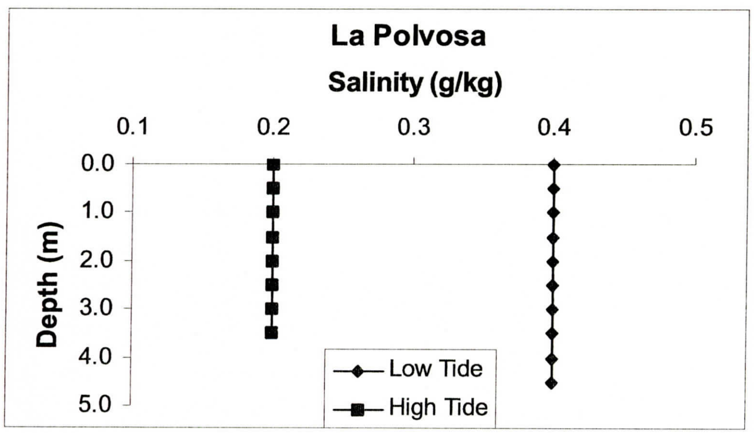


Figure 30. Dissolved oxygen profiles at high and low tide on 21-22 November 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

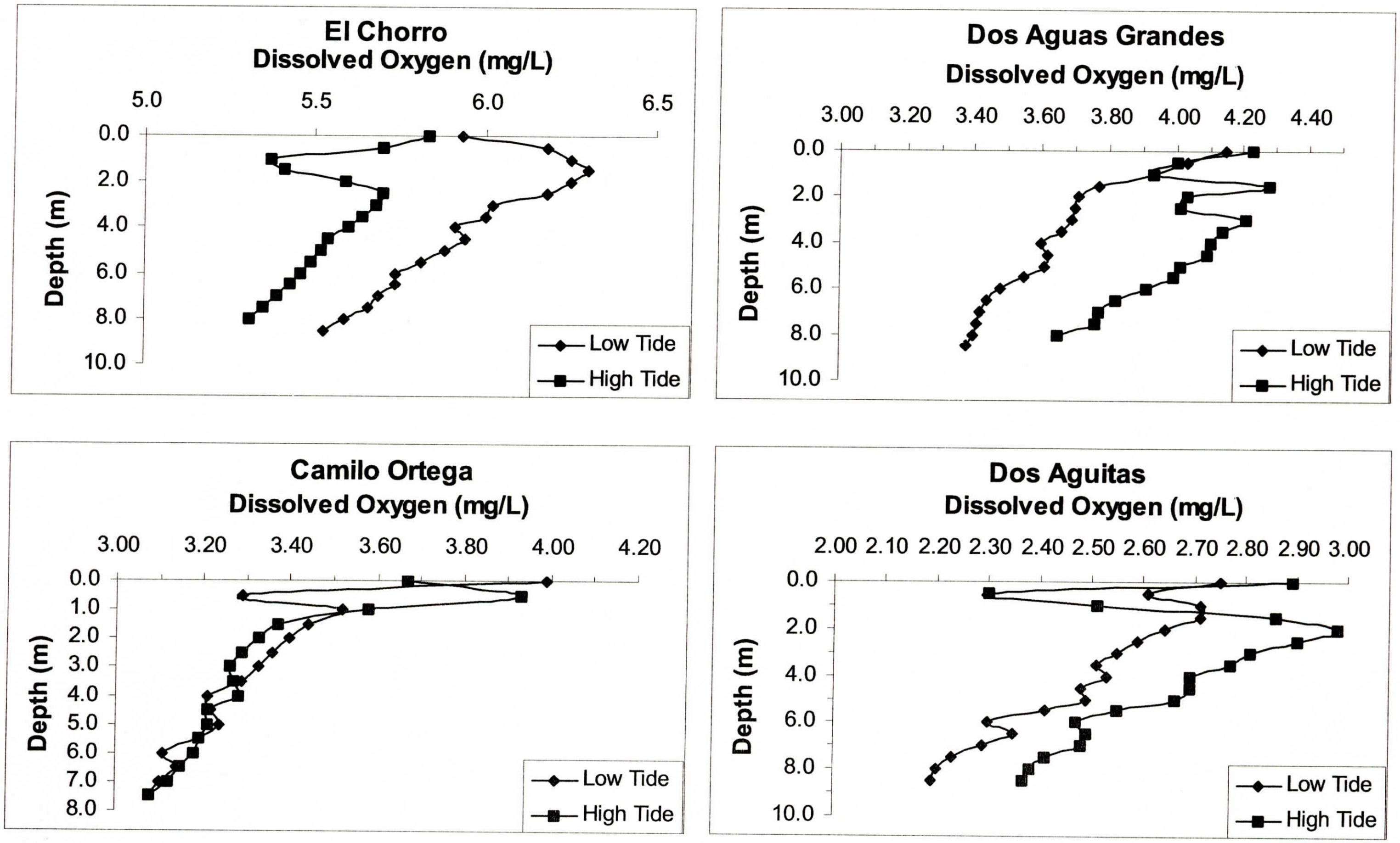


Figure 30 - continued. Dissolved oxygen profiles at high and low tide on 21-22 November 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.

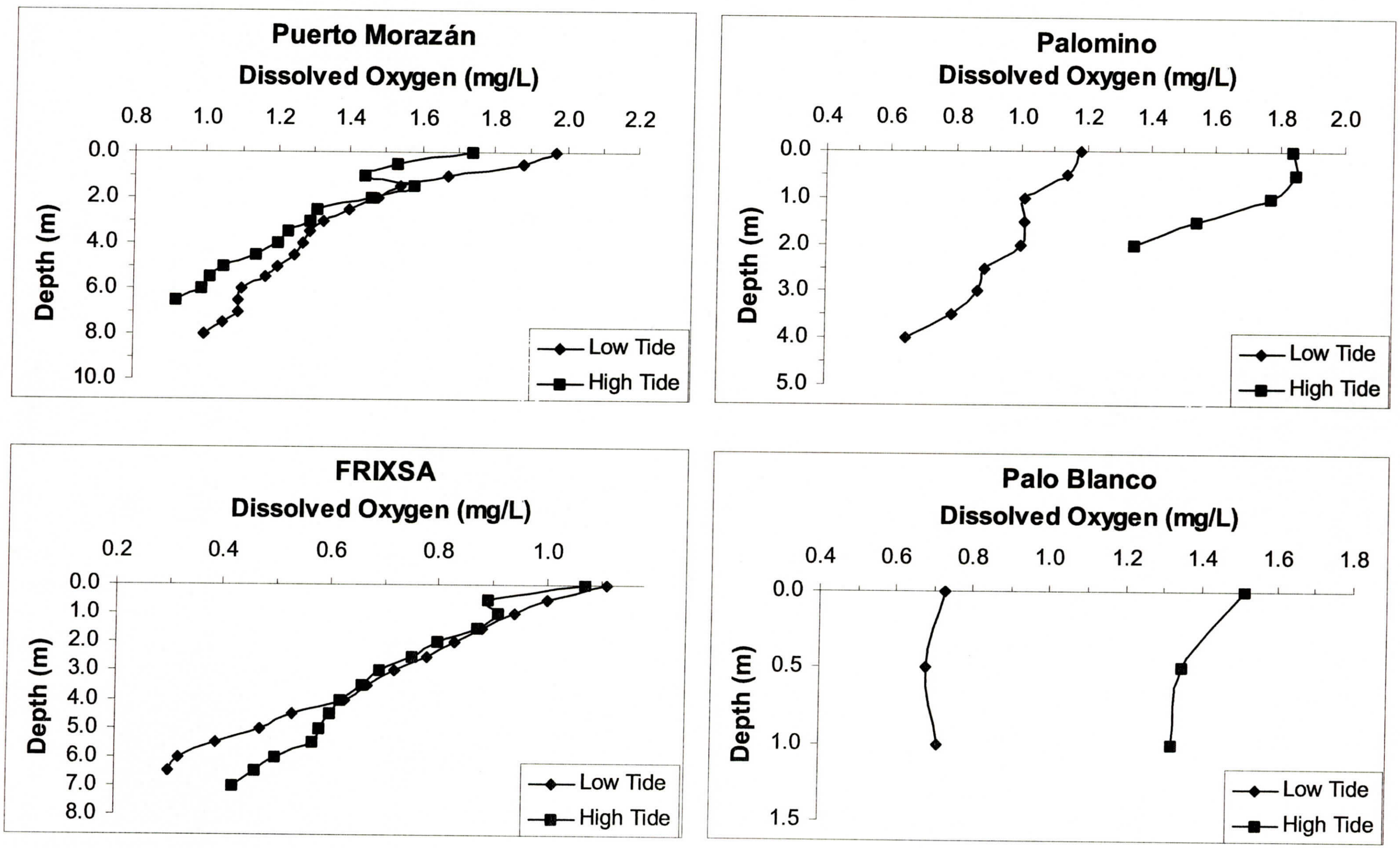
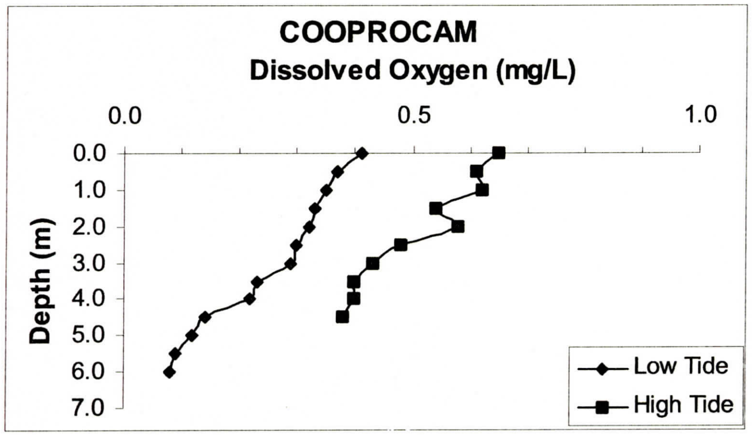
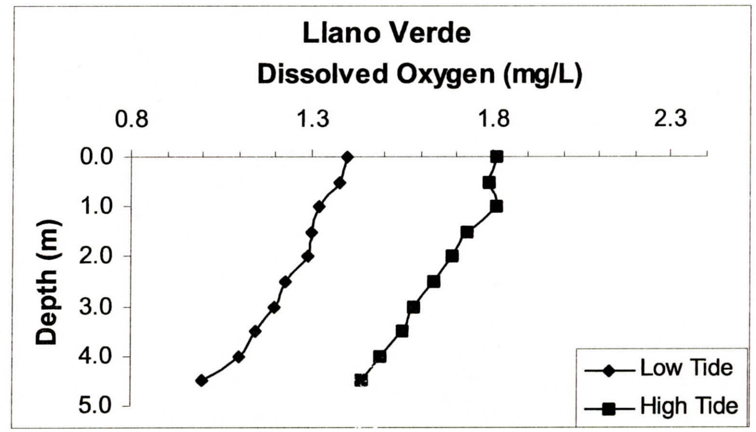


Figure 30 - continued. Dissolved oxygen profiles at high and low tide on 21-22 November 2001 at sample stations along the main channel of the Estero Real. Dissolved oxygen was measured at the surface and at 0.5-m depth intervals.





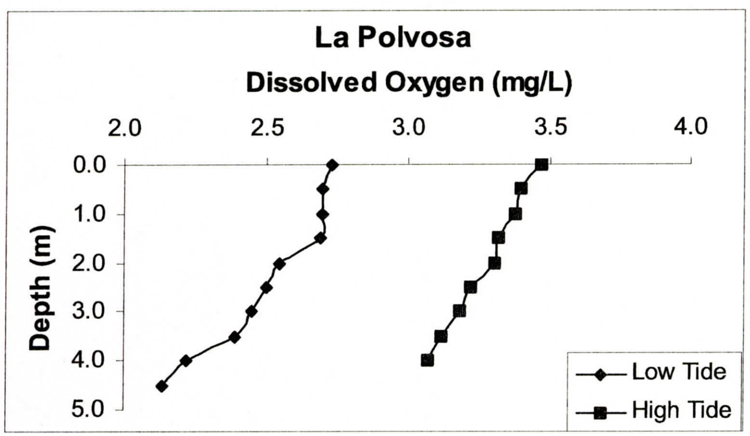


Figure 31. Salinity profiles at high and low tide on 21-22 November 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

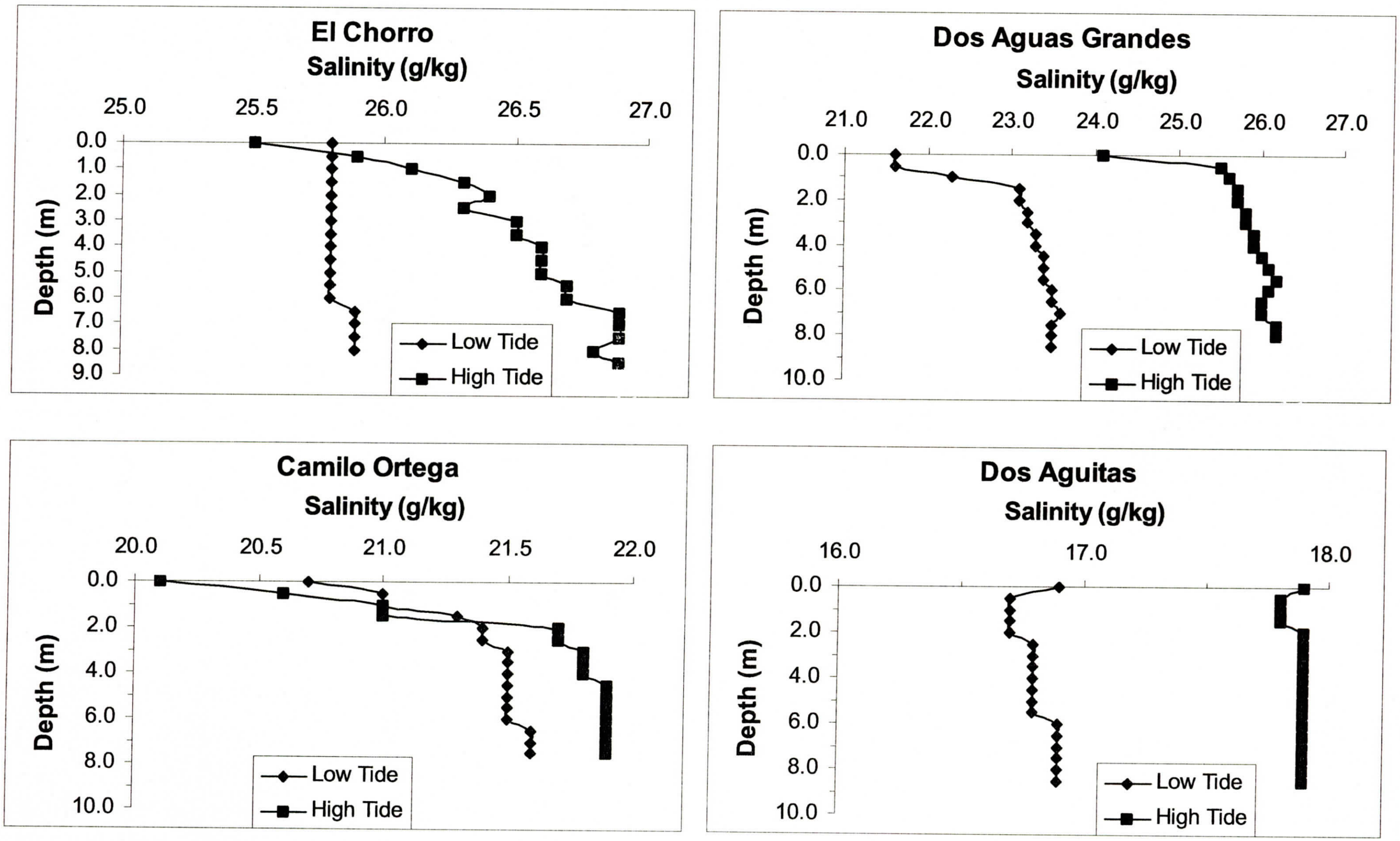


Figure 31 - continued. Salinity profiles at high and low tide on 21-22 November 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.

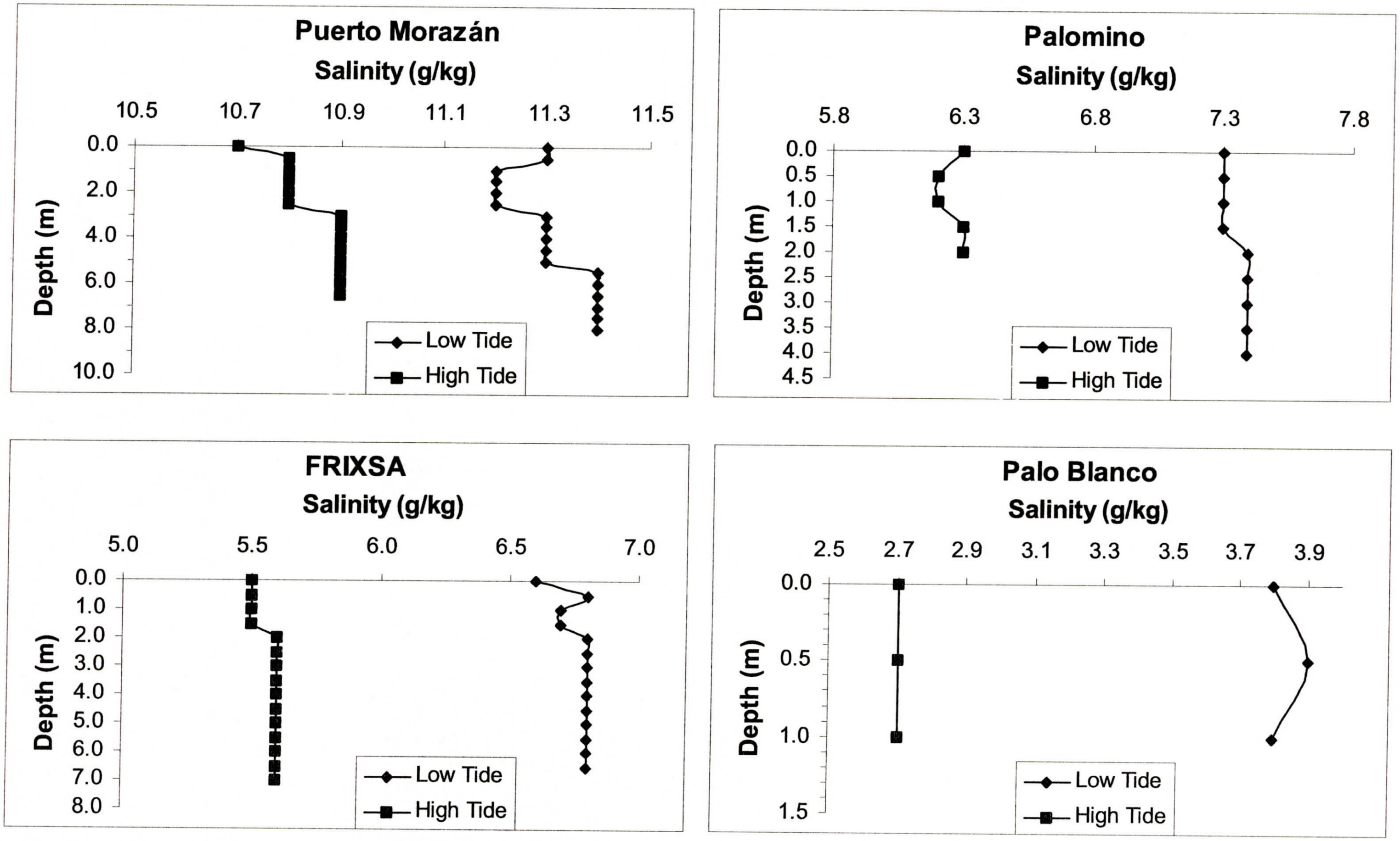
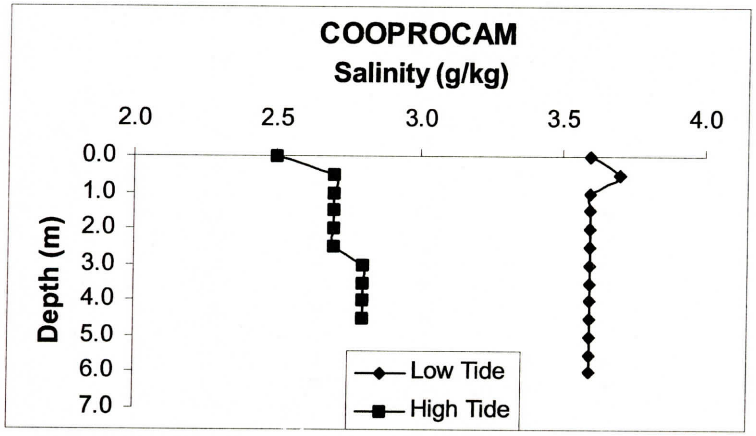
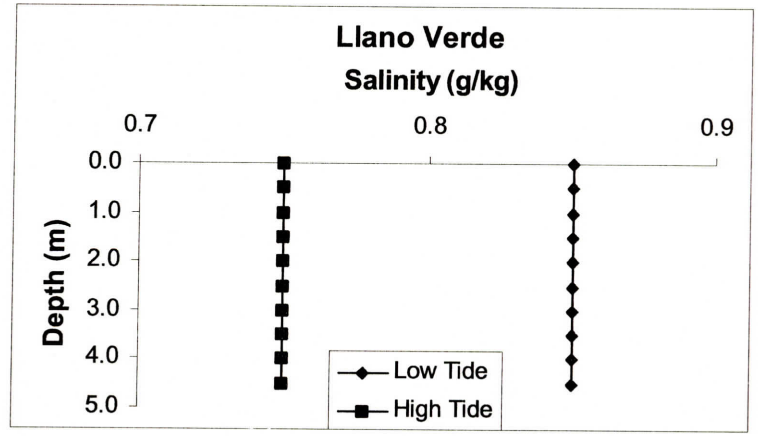
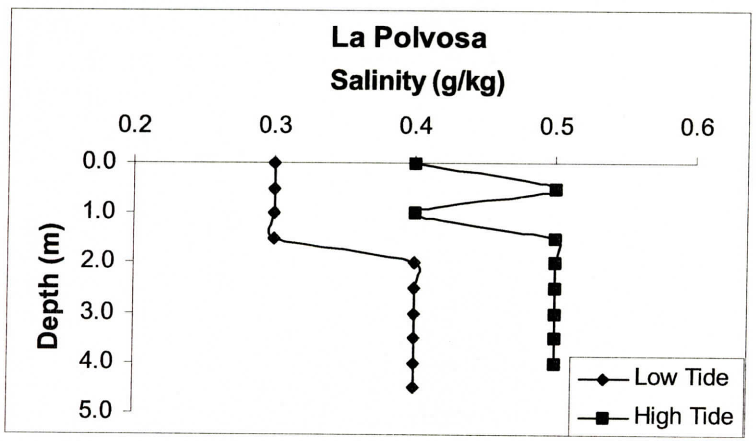


Figure 31 - continued. Salinity profiles at high and low tide on 21-22 November 2001 at sample stations along the main channel of the Estero Real. Salinity was measured at the surface and at 0.5-m depth intervals.







Current Velocity

Surface current velocity was measured at eleven sample stations (see Table 21) while the boat was anchored for measurement of the DO/T/Sal profiles during low and high tides each month. A 1-gallon plastic jug with a screw cap was used to measure surface current velocity. A 15-m, thin nylon cord was attached to the handle of the jug. The jug was filled with estuarine water, and with the boat at anchor the full jug was placed into the water, given a gentle push in the direction of the current, and the time the jug took to travel the 15 m was measured.

Results and Discussion

Current velocity measurements are presented in Table 21. Current velocity ranged from 0.15 m/s to 1.17 m/s. This data will be used in future development of a hydrodynamic model for the Estero Real as part of its carrying capacity model development.

Estuarine Bathimetry

In December 2000, extensive depth surveys of the Estero Real system were conducted using a recording sonar fathometer. The surveys were conducted beginning about two hours before high tide to about two hours after high tide. The depth surveys included cross-sectional and longitudinal transects (Figure 32, Table 22). Ward and Green (2001) described the functioning of the recording fathometer: "The transducer is fixed to the boat hull and placed less than a meter below the surface. As the boat moves, the transmitter portion of the transducer emits a series of high-frequency pings, while the receiver continually monitors sound level. The intensity of the received sound is converted to electrical current, which heats the stylus of the chart recorder thereby producing a mark on thermal-sensitive chart paper. Each swipe of the stylus across the width of the paper corresponds to a ping. Time elapsing after the ping is converted electronically to distance using the speed of sound in water. The initial ping produces a burn line, adjusted to agree with the depth of the transducer. Any echoes received at the transducer are shown as burn spots whose intensity is related to the amplitude of the sound. The bottom return is immediately evident as the dark cluster of lines. The width of these lines is due to reverberation, increasing the time duration of the received pulse. (When the gain of the receiver is set too high, a second return from the bottom may be recorded as a faint curve appearing to track parallel to the true bottom return.) … An example of the strip chart output and its interpretation is shown in Figure 33." For each cross section bathygram, the stern of the boat, where the transducer was mounted, was positioned as close to the edge of the estuary as possible. Generally, this was about 0.3 m into the mangrove canopy, or where a clear channel to the edge existed the boat was positioned in water about 0.5-m deep. A landmark on the other bank of the estuary was selected and the boat proceeded at constant velocity across the estuary. At the opposite bank, the boat continued until either the bow was 1-2 m into the mangrove canopy or touched the bank. The sonar bathygrams are presented in Appendix II.

This data will be used in future development of a hydrodynamic model for the Estero Real as part of its carrying capacity model development.

Table 21. Current velocity and direction at sample stations along Estero Real main channel during monthly determination of DO – temperature – salinity profiles.

	25 –26 June 2001		27 – 28 July 2001 High Tide	
Sample Station	Current (m/s)	Current Direction	Current (m/s)	Current Direction
El Chorro	0.17	To Gulf	0.32	From Gulf
Dos Aguas Grandes	0.15	From Gulf	0.40	From Gulf
Camilo Ortega	0.18	From Gulf	0.37	From Gulf
Dos Aguitas	0.78	From Gulf	0.47	From Gulf
Puerto Morazán	0.85	To Gulf	0.78	To Gulf
Palomino	0.79	To Gulf	1.10	To Gulf
FRIXSA	0.85	To Gulf	1.07	To Gulf
Palo Blanco	0.85	To Gulf	0.94	To Gulf
COOPROCAM	0.69	To Gulf	1.05	To Gulf
Llano Verde	0.71	To Gulf	0.98	To Gulf
La Polvosa	0.85	To Gulf	0.80	To Gulf

	22 – 23 August 2001 High Tide		19 – 20 September 2001 High Tide	
Sample Station	Current (m/s)	Current Direction	Current (m/s)	Current Direction
El Chorro	0.52	From Gulf	0.78	To Gulf
Dos Aguas Grandes	0.58	From Gulf	0.83	To Gulf
Camilo Ortega	0.80	From Gulf	0.80	To Gulf
Dos Aguitas	0.38	From Gulf	0.81	To Gulf
Puerto Morazán	0.76	From Gulf	0.76	To Gulf
Palomino	0.38	From Gulf	0.79	To Gulf
FRIXSA	0.48	From Gulf	0.88	To Gulf
Palo Blanco	0.33	From Gulf	0.57	To Gulf
COOPROCAM	0.23	From Gulf	1.00	To Gulf
Llano Verde	0.23	From Gulf	0.96	To Gulf
La Polvosa	0.34	From Gulf	0.70	To Gulf

Table 21 - continued. Current velocity and direction at sample stations along Estero Real main channel during monthly determination of DO – temperature – salinity profiles.

	17 – 18 October 2001 High Tide		21 – 22 November 2001 Low Tide	
Sample Station	Current (m/s)	Current Direction	Current (m/s)	Current Direction
El Chorro	0.71	To Gulf	-	-
Dos Aguas Grandes	1.01	To Gulf	-	-
Camilo Ortega	0.64	To Gulf	0.44	To Gulf
Dos Aguitas	0.61	To Gulf	0.34	To Gulf
Puerto Morazán	1.00	To Gulf	0.57	To Gulf
Palomino	1.17	To Gulf	0.54	To Gulf
FRIXSA	0.87	To Gulf	0.56	To Gulf
Palo Blanco	0.92	To Gulf	0.34	To Gulf
COOPROCAM	0.77	To Gulf	0.56	To Gulf
Llano Verde	0.91	To Gulf	0.67	To Gulf
La Polvosa	0.83	To Gulf	0.89	To Gulf

Figure 32. Location of cross-sectional depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer.

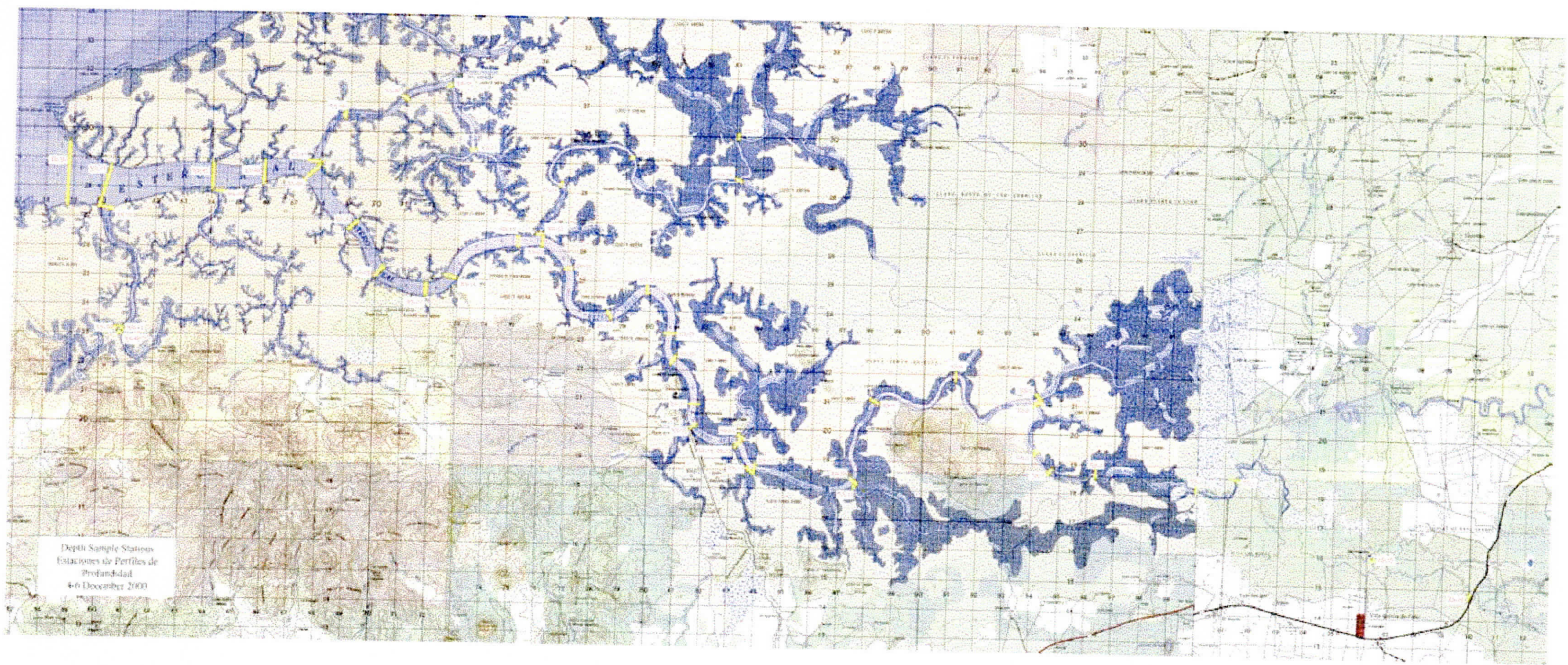


Table 22. Information on cross-sectional and longitudinal depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer. Information for each sounding includes date, time, section identification (XS = cross section; Long = longitudinal), and section information.

Depth Tracing ID Number(s)	Date	Time	ID	Tide Info	Sounding Info
REAL-01	4-Dec-00	9:30	XS1	High tide	Cross section 1, La Polvosa, N12 50.406', W086 58.810'
REAL-02, REAL-03, REAL-04	4-Dec-00		Long		Longitudinal transect from station XS1 to station XS2
REAL-05	4-Dec-00	9:50	XS2	Hide tide, current to Gulf	Cross section 2, Llano Verde, N12 49.744', W086 59.833'
REAL-06, REAL-07, REAL-08, REAL-09, REAL-10, REAL-11	4-Dec-00		Long		Longitudinal transect from station XS2 to station XS3
REAL-12	4-Dec-00	10:14	XS3	High tide, current to Gulf	Cross section 3, N12 50.149', W087 02.105'
REAL-13, REAL-14	4-Dec-00		Long		Longitudinal transect from station XS3 to station XS4
REAL-15	4-Dec-00	10:22	XS4	7/8 high tide, current to Gulf	Cross section 4, N12 50.131', W087 02.914'
REAL-16, REAL-17	4-Dec-00		Long		Longitudinal transect from station XS4 to station XS5
REAL-18	4-Dec-00	10:35	XS5	7/8 high tide, current to Gulf	Cross section 5, N12 50.737', W087 03.403'
REAL-19	4-Dec-00	10:50	XS6	3/4 high tide, current to Gulf	Cross section 6, Palo Blanco, N12 51.410', W087 03.244'
REAL-20	4-Dec-00	11:00	XS7	3/4 high tide, current to Gulf	Cross section 7, Palo Blanco, N12 51.450', W087 03.226'
REAL-21, REAL-22, REAL-23, REAL-24	4-Dec-00		Long		Longitudinal transect from station XS6 to station XS8. Note there was a break in coverage between REAL-21 and REAL-22 because equipment malfunctioned. Break in coverage was not very long, but exact distance is unknown.
REAL-25	4-Dec-00	11:28	XS8	3/4 high tide, current to Gulf	Cross section 8, N12 51.869', W087 05.109'
REAL-26, REAL-27, REAL-28, REAL-29	4-Dec-00		Long		Longitudinal transect from station XS8 to station XS9
REAL-30	4-Dec-00	11:48	XS9	3/4 high tide, current to Gulf	Cross section 9, FRIXSA, N12 51.098', W087 06.712'

Table 22 - continued. Information on cross-sectional and longitudinal depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer. Information for each sounding includes date, time, section identification (XS = cross section; Long = longitudinal), and section information.

Depth Tracing ID Number(s)	Date	Time	ID	Tide Info	Sounding Info
REAL-31, REAL-32	4-Dec-00		Long		Longitudinal transect from station XS9 to station XS10
REAL-33	4-Dec-00	12:01	XS10	5/8 high tide, current to Gulf	Cross section 10, Estero Palomino, N12 49.848', W087 06.879'
REAL-34	4-Dec-00	12:08	XS11	5/8 high tide, current to Gulf	Cross section 11, Estero Palomino, N12 49.832', W087 06.886'
REAL-35, REAL-36, REAL-37, REAL-38	4-Dec-00		Long		Longitudinal transect from station XS11 to station XS12
REAL-39	4-Dec-00	12:24	XS12	5/8 high tide, current to Gulf	Cross section 12, N12 50.039', W087 08.914'
REAL-40	4-Dec-00	12:29	XS13	5/8 high tide, current to Gulf	Cross section 13, N12 50.041', W087 08.925'
REAL-41	4-Dec-00		Long		Longitudinal transect from station XS13 to station XS14
REAL-42	4-Dec-00	12:34	XS14	5/8 high tide, current to Gulf	Cross section 14, N12 50.628', W087 09.220'
REAL-43	4-Dec-00	12:40	XS15	5/8 high tide, current to Gulf	Cross section 15, Estero Canta Gallo, N12 50.634', W087 09.214'
REAL-44	4-Dec-00		Long		Longitudinal transect in vicinity of XS14
REAL-45	5-Dec-00	8:04	XS16	1/2 high tide, current from gulf	Cross section 16, N12 53.798', W087 16.765'
REAL-46	5-Dec-00		Long		Longitudinal transect from station XS16 to station XS17
REAL-47	5-Dec-00	8:25	XS17	1/2 high tide, current from gulf	Cross section 17, Camilo Ortega, N12 53.202', W087 15.801'
REAL-48	5-Dec-00	8:36	XS18	1/2 high tide, current from gulf	Cross section 18, N12 53.497', W087 14.991'
REAL-49	5-Dec-00		Long		Longitudinal transect from station XS18 to station XS19
REAL-50	5-Dec-00	8:50	XS19	5/8 high tide, current from Gulf	Cross section 19, N12 54.121', W087 13.906'

Table 22 - continued. Information on cross-sectional and longitudinal depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer. Information for each sounding includes date, time, section identification (XS = cross section; Long = longitudinal), and section information.

Depth Tracing ID Number(s)	Date	Time	ID	Tide Info	Sounding Info
REAL-51	5-Dec-00	9:02	XS20	5/8 high tide, current from Gulf	Cross section 20, Dos Aguitas, N12 54.367', W087 13.224'
REAL-51	5-Dec-00	9:08	XS21	5/8 high tide, current from Gulf	Cross section 21, N12 54.380', W087 13.243'
REAL-52	5-Dec-00		Long		Longitudinal transect from station XS21 to station XS22
REAL-52	5-Dec-00	9:16	XS22	5/8 high tide, current from Gulf	Cross section 22, N12 55.330', W087 12.842'
REAL-53, REAL-54	5-Dec-00		Long		Longitudinal transect from station XS22 to station XS23
REAL-54	5-Dec-00	9:29	XS23	5/8 high tide, current from Gulf	Cross section 23, Dos Aguitas (antes de Perejiles), N12 55.797', W087 11.504'
REAL-55, REAL-56	5-Dec-00		Long		Longitudinal transect from station XS23 to station XS24
REAL-57	5-Dec-00	9:50	XS24	3/4 high tide, current from Gulf	Cross section 24, N12 55.494', W087 09.387'
REAL-57	5-Dec-00		Long		Longitudinal transect from station XS24 to station XS25
REAL-58	5-Dec-00	9:56	XS25	3/4 high tide, current from Gulf	Cross section 25
REAL-59	5-Dec-00	10:24	XS26	7/8 high tide, current from Gulf	Cross section 26
REAL-59, REAL-60	5-Dec-00		Long		Longitudinal transect from station XS26 to station XS27
REAL-61	5-Dec-00	10:38	XS27	high tide	Cross section 27, N12 52.853', W087 11.722'
REAL-61	5-Dec-00		Long		Longitudinal section from station XS27 to station XS28
REAL-62	5-Dec-00	10:46	XS28	high tide	Cross section 28, N12 53.453', W087 11.194'
REAL-62	5-Dec-00		Long		Longitudinal transect from station XS28 to station XS29
REAL-63	5-Dec-00	10:54	XS29	High tide, current to Gulf	Cross section 29, N12 52.944', W087 10.578'

Table 22 - continued. Information on cross-sectional and longitudinal depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer. Information for each sounding includes date, time, section identification (XS = cross section; Long = longitudinal), and section information.

Depth Tracing ID Number(s)	Date	Time	ID	Tide Info	Sounding Info
REAL-63	5-Dec-00		Long		Longitudinal transect from station XS29 to station XS30
REAL-64	5-Dec-00	11:05	XS30	High tide, current to Gulf	Cross section 30, N12 52.029', W087 10.648'
REAL-64, REAL-65	5-Dec-00		Long		Longitudinal transect from station XS30 to station XS31
REAL-66	5-Dec-00	11:14	XS31	7/8 high tide, current to Gulf	Cross section 31, Puerto Morazan, N12 51.299', W087 10.251'
REAL-66	5-Dec-00		Long		Longitudinal transect from station XS31 to station XS32
REAL-67	5-Dec-00		XS32		Cross section 32
REAL-67	5-Dec-00		Long		Longitudinal transect from station XS32 to XS33
REAL-68	5-Dec-00	11:30	XS33	3/4 high tide, current to Gulf	Cross section 33, N12 50.526', W087 09.280'
REAL-68	5-Dec-00	13:59	XS34	1/2 high tide, current to Gulf	Cross section 34, Puente Real (carretera), N12 48.009', W086 54.459'
REAL-69, REAL-70, REAL-71, REAL-72, REAL-73, REAL-74, REAL-75,REAL-76, REAL-77	5-Dec-00		Long		Longitudinal transect from station XS34 to station XS35
REAL-78	5-Dec-00	15:09	XS35	3/4 low tide, current to Gulf	Cross section 35, N12 48.690', W086 56.739'
REAL-79, REAL-80, REAL-81, REAL-82	6-Dec-00	8:41	XS36	1/2 high tide, current from Gulf	Cross section 36, mouth of Estero Real, start 0841 h: N12 56.435', W087 23.067'; finish 0905 h: N12 55.185', W087 25.447'
REAL-82, REAL-83, REAL-84, REAL-85, REAL-86	6-Dec-00		Long		Longitudinal transect from station XS36 to station XS37
REAL-86, REAL-87	6-Dec-00	9:36	XS37	5/8 high tide, current from Gulf	Cross section 37, El Chorro, start 0936 h: N12 55.555', W087 21.835'; finish: 0943 h: N12 54.764', W087 22.131'
REAL-88	6-Dec-00	9:46	XS38	5/8 high tide, current from Gulf	Cross section 38, N12 54.751', W087 22.112'

Table 22 - continued. Information on cross-sectional and longitudinal depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer. Information for each sounding includes date, time, section identification (XS = cross section; Long = longitudinal), and section information.

Depth Tracing ID Number(s)	Date	Time	ID	Tide Info	Sounding Info
REAL-88, REAL-89	6-Dec-00		Long		Longitudinal transect from station XS38 to station XS39
REAL-90	6-Dec-00	10:02	XS39	5/8 high tide, current from Gulf	Cross section 39, N12 52.529', W087 21.753'
REAL-90	6-Dec-00	10:06	XS40	3/4 high tide, current from Gulf	Cross section 40, start 1006 h: N12 52.457', W087 21.699'; finish 1008 h: N12 52.444', W087 21.640'
REAL-90	6-Dec-00	10:09	XS41	3/4 high tide, current from Gulf	Cross section 41, start 1009 h: N12 52.470', W087 21.640'; finish 1011 h: N12 52.535', W087 21.675'
REAL-91, REAL-92, REAL-93	6-Dec-00		Long		Longitudinal transect from station XS41 to station XS42
REAL-94	6-Dec-00	10:31	XS42	3/4 high tide, current from Gulf	Cross section 42, start 1031 h: N12 55.600', W087 19.867'; finish 1037 h: N12 55.085', W087 19.814'
REAL-95	6-Dec-00	10:40	XS43	3/4 high tide, current from Gulf	Cross section 43, start 1040 h: N12 55.036', W087 19.763'; finish 1043 h: N12 55.043', W087 19.683'
REAL-95	6-Dec-00	10:55	XS44	7/8 high tide, current from Gulf	Cross section 44, start 1055 h: N12 55.675', W087 18.786'; finish 1100 h: N12 55.323', W087 18.622'
REAL-95	6-Dec-00	11:05	XS45	7/8 high tide, current from Gulf	Cross section 45, start 1105 h: N12 55.701', W087 17.888'; finish 1110 h: N12 55.613', W087 17.730'
REAL-96	6-Dec-00	11:13	XS46	7/8 high tide, current from Gulf	Cross section 46, Dos Aguas Grandes, start 1113 h: N12 55.505', W087 17.690'; finish 1116 h: N12 55.238', W087 17.958'
REAL-96	6-Dec-00	11:23	XS47	high tide	Cross section 47, start 1123 h: N12 54.391', W087 17.165'; finish 1127 h: N12 54.577', W087 16.919'

Table 22 - continued. Information on cross-sectional and longitudinal depth surveys conducted in the Estero Real system in December 2000 using a recording sonar fathometer. Information for each sounding includes date, time, section identification (XS = cross section; Long = longitudinal), and section information.

REAL-96	6-Dec-00	11:37	XS48	high tide	Cross section 48, start 1137 h: N12 56.502', W087 17.169'; finish 1141 h: N12 56.611', W087 17.206'
REAL-97	6-Dec-00	11:47	XS49	7/8 high tide, current to Gulf	Cross section 49, start 1147 h: N12 56.855', W087 16.069'; finish 1150 h: N12 56.947', W087 16.091'
REAL-97	6-Dec-00	11:55	XS50	7/8 high tide, current to Gulf	Cross section 50, Dos Aguas Grandes (El Angelino), start 1155 h: N12 57.136', W087 15.136'; finish 1203 h: N12 57.074', W087 15.217'
REAL-97	6-Dec-00	12:09	XS51	7/8 high tide, current to Gulf	Cross section 51, start 1209 h: N12 56.078', W087 14.737'; finish 1211 h: N12 56.100', W087 14.650'

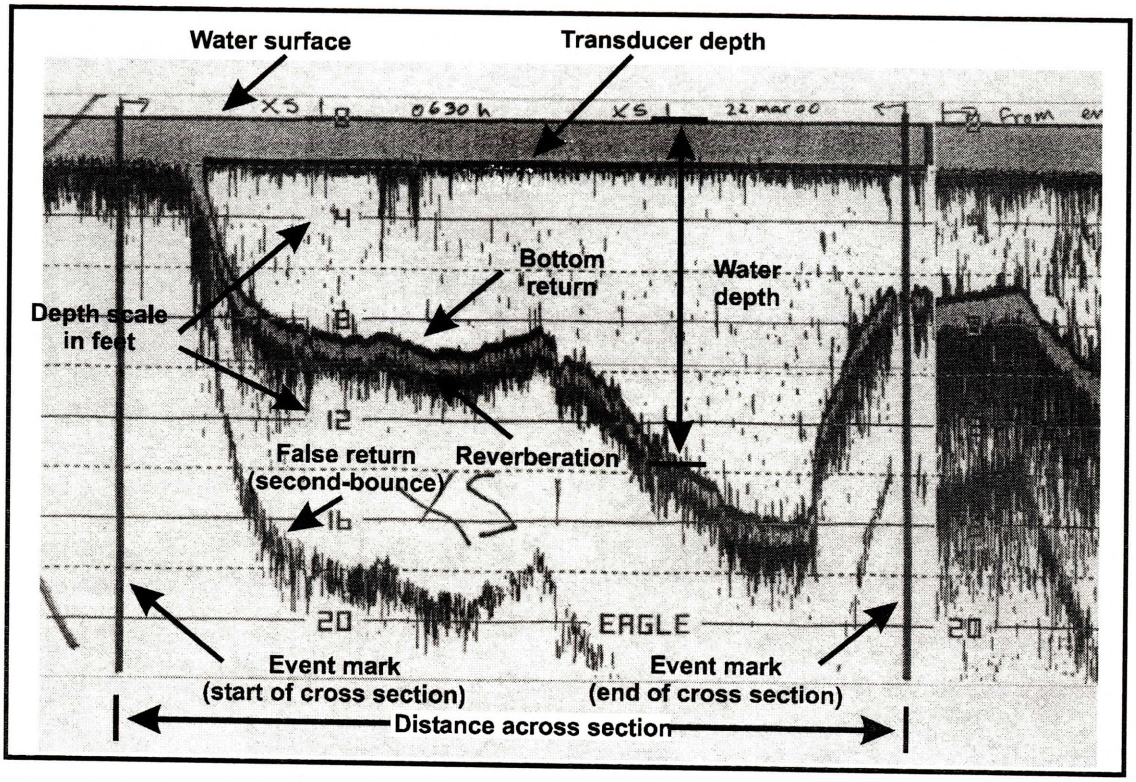


Figure 33. Section of sonar bathygram showing principal features of interpretation (*from* Ward and Green, 2001).

Tide Gauges

Tide gauges were installed at four points along the Estero Real in order to collect data that will be used in the future to relate the actual height of the tide at each sample site to tide height at the La Union, El Salvador, tide-gauging station. Tide gauges were constructed of strips of schedule 40 PVC pipe onto which was painted a numeric scale in 1-cm intervals. Gauges were mounted such that the scale extended 25 cm below the lowest water level and 25 cm above the highest water level. Gauges were placed along the main channel of the Estero Real at El Chorro, Camilo Ortega, Puerto Morazán, and Cooperative LAN Number 1 (12 51.9' N, 87 5.1' W). The positioning of each tide gauge was arbitrary with regard to initial placement of the numeric scale and any other landmark. Tide height measurements are relative, and are related only to measurements made at the same gauge. Thus, tide gauges were not moved once installation was complete. However, tide gauges had to be re-leveled on a couple of occasions because tidal currents had moved the gauge off perpendicular. Observations were recorded in an opportunistic manner, with multiple observations occurring at 2-hour intervals on some dates, while on other dates there was one or no observation made.

Results and Discussion

Results of tide height observations are given in Table 23. Examples of tidal range and variation in tide form at La Union, El Salvador, and Puerto Morazán, Nicaragua, are shown in Figure 34.

This data will be used in future development of a hydrodynamic model for the Estero Real as part of its carrying capacity model development.

Table 23. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 1-5 August 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
1 Aug 01	0600 h			10	
	0800 h				307
	1000 h		127	150	77
	1200 h			240	324
	1400 h			300	
	1600 h				120
	1800 h				
2 Aug 01	0600 h				
	0800 h		8		
	1000 h		136		
	1200 h		245		
	1400 h		201	317	
	1600 h		96		
	1800 h				
3 Aug 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
4 Aug 01	0600 h				
	0800 h				125
	1000 h				98
	1200 h				21
	1400 h				
	1600 h				
	1800 h				
5 Aug 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 6 - 10 August 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
6 Aug 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
7 Aug 01	0600 h				
	0800 h	87			290
	1000 h				
	1200 h				5
	1400 h				127
	1600 h				35
	1800 h				397
8 Aug 01	0600 h				***380
	0800 h	87	225		315
	1000 h		278		173
	1200 h		135		49
	1400 h		160		57
	1600 h		190	220	277
	1800 h		290		
9 Aug 01	0600 h		290	300	
	0800 h		150	400	
	1000 h			110	
	1200 h		1	22	
	1400 h		45		
	1600 h		190	170	
	1800 h		290	298	
10 Aug 01	0600 h		275	280	342
	0800 h		281	314	380
	1000 h		176	210	120
	1200 h		45	68	269
	1400 h		0		385
	1600 h		136	120	234
	1800 h		261	260	

*** Tide gauge was re-installed.

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 11 - 15 August 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
11Aug 01	0600 h		245	240	
	0800 h		287	309	25
	1000 h		228	260	72
	1200 h		110	110	220
	1400 h				372
	1600 h		107	77	324
	1800 h		232	220	132
12 Aug 01	0600 h		219	190	248
	0800 h		260	294	40
	1000 h		210	300	31
	1200 h			170	160
	1400 h		20	38	302
	1600 h		5		361
	1800 h			150	21
13 Aug 01	0600 h		166	165	23
	0800 h		262	267	85
	1000 h		274	298	39
	1200 h		188	220	
	1400 h		74	96	
	1600 h		19		
	1800 h		115	99	
14 Aug 01	0600 h		102	80	276
	0800 h		210	200	
	1000 h		277	300	
	1200 h		145	280	
	1400 h		125	146	
	1600 h		15	30	32
	1800 h		57	37	360
15 Aug 01	0600 h		32	10	364
	0800 h		157	148	214
	1000 h		261	360	22
	1200 h		280	305	30
	1400 h		160	226	124
	1600 h		102	90	
	1800 h				360

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 16 – 20 August 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
16 Aug 01	0600 h			4	240
	0800 h		70	50	334
	1000 h		219	203	150
	1200 h			306	
	1400 h		210	305	
	1600 h			160	164
	1800 h		20	30	33
17 Aug 01	0600 h			45	322
	0800 h		42		
	1000 h		135	120	155
	1200 h		285	270	318
	1400 h		315	336	
	1600 h		227	260	330
	1800 h			95	
18 Aug 01	0600 h		60	104	
	0800 h				
	1000 h		170		
	1200 h		219	206	240
	1400 h		320	335	390
	1600 h		290	338	378
	1800 h		230		
19 Aug 01	0600 h		198	334	
	0800 h		125		
	1000 h			***	
	1200 h		166	104	110
	1400 h		330	302	358
	1600 h		363	360	42
	1800 h		250	315	371
20 Aug 01	0600 h		275	327	
	0800 h		65	134	
	1000 h				
	1200 h		60		
	1400 h		250	255	
	1600 h		355	355	
	1800 h		325	364	

*** Tide gauge re-installed.

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 21 - 25 August 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
21 Aug 01	0600 h		327	365	
	0800 h		107	245	
	1000 h				
	1200 h				
	1400 h		170	130	
	1600 h		355	328	
	1800 h		350	369	
22 Aug 01	0600 h		327	366	
	0800 h		107	335	
	1000 h			129	
	1200 h				
	1400 h		170		
	1600 h	195	315	253	
	1800 h		350	359	
23 Aug 01	0600 h		350	352	
	0800 h	209		358	
	1000 h			208	
	1200 h				
	1400 h		100		
	1600 h		298	180	
	1800 h		341		
24 Aug 01	0600 h		345	324	
	0800 h			359	
	1000 h		100	280	
	1200 h			80	
	1400 h				
	1600 h			90	
	1800 h			283	
25 Aug 01	0600 h			257	
	0800 h			347	
	1000 h			300	
	1200 h			145	
	1400 h				
	1600 h				
	1800 h			205	

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 26 - 30August 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
26 Aug 01	0600 h			180	
	0800 h			310	
	1000 h			320	
	1200 h			185	
	1400 h			40	
	1600 h				
	1800 h			140	
27 Aug 01	0600 h			105	
	0800 h			255	
	1000 h			315	
	1200 h			245	
	1400 h			48	
	1600 h				
	1800 h				
28 Aug 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
29 Aug 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
30 Aug 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 1 – 5 September 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
1 Sep 01	0600 h		60	170	148
	0800 h			8	
	1000 h				9
	1200 h			200	
	1400 h			290	
	1600 h			265	
	1800 h				
2 Sep 01	0600 h			188	142
	0800 h				5
	1000 h				
	1200 h				
	1400 h				270
	1600 h				330
	1800 h				
3 Sep 01	0600 h				160
	0800 h			75	60
	1000 h			- 25	
	1200 h			80	
	1400 h			238	230
	1600 h			315	320
	1800 h				
4 Sep 01	0600 h				136
	0800 h				264
	1000 h				
	1200 h				
	1400 h				
	1600 h				221
	1800 h				
5 Sep 01	0600 h	***			84
	0800 h		***		201
	1000 h	136		***	***
	1200 h				
	1400 h				
	1600 h			308	
	1800 h			318	

*** Tide gauge re-installed.

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 6 - 10 September 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
6 Sep 01	0600 h			310	
	0800 h			220	202
	1000 h	109	65	67	314
	1200 h			-25	
	1400 h			80	
	1600 h				
	1800 h			300	
7 Sep 01	0600 h		310		644
	0800 h		190	267	171
	1000 h		72	104	284
	1200 h			-25	
	1400 h		63	10	
	1600 h		170	190	
	1800 h		302		
8 Sep 01	0600 h		360	305	64
	0800 h		200	295	111
	1000 h		135	155	223
	1200 h			-25	366
	1400 h		43	-25	
	1600 h		120	137	253
	1800 h		290		16
9 Sep 01	0600 h		280	284	18
	0800 h		290	300	69
	1000 h		160	190	
	1200 h		45		338
	1400 h		80	-25	
	1600 h		170	164	290
	1800 h		245	235	156
10 Sep 01	0600 h		235		141
	0800 h		299	310	81
	1000 h		255	255	125
	1200 h		98	100	300
	1400 h			-25	
	1600 h		90	-5	
	1800 h		270		222

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 11 -15 September 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
11 Sep 01	0600 h			190	240
	0800 h			285	280
	1000 h			275	290
	1200 h			154	190
	1400 h			25	18
	1600 h			-17	
	1800 h			130	
12 Sep 01	0600 h			120	
	0800 h			150	
	1000 h			193	
	1200 h			228	
	1400 h			88	
	1600 h			-25	
	1800 h				
13 Sep 01	0600 h			34	
	0800 h			180	
	1000 h				
	1200 h				
	1400 h			154	
	1600 h				
	1800 h			5	
14 Sep 01	0600 h			-25	
	0800 h		115		80
	1000 h		230		210
	1200 h		297	290	325
	1400 h		290	240	
	1600 h		103	110	160
	1800 h			20	65
15 Sep 01	0600 h			14	10
	0800 h		20	15	
	1000 h		148	160	110
	1200 h		287	275	282
	1400 h		300	322	380
	1600 h		208	210	290
	1800 h		25	64	90

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 16 - 20 September 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
16 Sep 01	0600 h		60	64	60
	0800 h			-27	
	1000 h		69	60	55
	1200 h		270	200	220
	1400 h		324	343	330
	1600 h			290	220
	1800 h		70		160
17 Sep 01	0600 h		60	190	180
	0800 h			-25	20
	1000 h			-25	
	1200 h			120	98
	1400 h		315	310	330
	1600 h		325	345	360
	1800 h		246		290
18 Sep 01	0600 h		267	300	340
	0800 h			95	240
	1000 h			-25	
	1200 h		58	-25	
	1400 h		268	245	230
	1600 h		340	345	360
	1800 h			330	
19 Sep 01	0600 h				380
	0800 h				
	1000 h	78			310
	1200 h				
	1400 h			160	
	1600 h			337	
	1800 h				
20 Sep 01	0600 h				
	0800 h	221			
	1000 h			360	
	1200 h				
	1400 h				
	1600 h				
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 21 - 25 September 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
21 Sep 01	0600 h		213		356
	0800 h			317	360
	1000 h			160	164
	1200 h			-25	
	1400 h			-25	
	1600 h			210	
	1800 h				
22 Sep 01	0600 h			337	
	0800 h			280	
	1000 h			220	
	1200 h			7	
	1400 h			-25	
	1600 h			145	
	1800 h				
23 Sep 01	0600 h			279	
	0800 h			318	
	1000 h			242	
	1200 h			50	
	1400 h				
	1600 h			187	
	1800 h			238	
24 Sep 01	0600 h			210	
	0800 h			298	
	1000 h			270	
	1200 h			105	
	1400 h			-25	
	1600 h				
	1800 h				
25 Sep 01	0600 h			140	
	0800 h				
	1000 h				
	1200 h			165	
	1400 h			50	
	1600 h				
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 26 - 30 September 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
26 Sep 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
27 Sep 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
28 Sep 01	0600 h		45	36	
	0800 h		100	75	
	1000 h		200	210	
	1200 h		260	250	
	1400 h		245	230	
	1600 h		120	120	
	1800 h		60		
29 Sep 01	0600 h		38		
	0800 h		55	10	
	1000 h		125	125	
	1200 h		277	250	
	1400 h		250	270	
	1600 h		148	170	
	1800 h		75		
30 Sep 01	0600 h			76	
	0800 h		50	-12	
	1000 h			67	
	1200 h			200	
	1400 h		260	280	
	1600 h			240	
	1800 h		110		

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 1 – 5 October 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
1 Oct 01	0600 h		100		
	0800 h		5	-25	
	1000 h		58	-10	
	1200 h		195	160	
	1400 h		292	290	
	1600 h		240	280	
	1800 h				
2 Oct 01	0600 h		140	180	
	0800 h		-1	-15	
	1000 h		37	-25	
	1200 h		204	105	
	1400 h		265	265	
	1600 h		282	305	
	1800 h			200	
3 Oct 01	0600 h		140		
	0800 h	41	45	70	
	1000 h		10	-25	
	1200 h			20	
	1400 h			220	
	1600 h			310	
	1800 h				
4 Oct 01	0600 h		226	280	
	0800 h		95	125	
	1000 h	115	160	-25	
	1200 h		200	-25	
	1400 h		300	185	
	1600 h		280	305	
	1800 h			295	
5 Oct 01	0600 h		280		
	0800 h		101	217	
	1000 h			-15	
	1200 h			-25	
	1400 h				
	1600 h			278	
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 6 - 10 October 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
6 Oct 01	0600 h			330	
	0800 h	***			
	1000 h			60	
	1200 h			-25	
	1400 h			75	
	1600 h			240	
	1800 h			320	
7 Oct 01	0600 h			330	
	0800 h			270	
	1000 h			80	
	1200 h			-25	
	1400 h			65	
	1600 h			202	
	1800 h			300	
8 Oct 01	0600 h				
	0800 h			315	
	1000 h			185	
	1200 h			20	
	1400 h			-25	
	1600 h			120	
	1800 h			290	
9 Oct 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h				
	1600 h				
	1800 h				
10 Oct 01	0600 h			210	246
	0800 h			300	345
	1000 h			260	23
	1200 h			140	
	1400 h			20	
	1600 h				

*** Tide gauge re-intsalled.

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 11 - 15 October 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
11 Oct 01	0600 h			140	148
	0800 h				
	1000 h			295	
	1200 h			210	198
	1400 h			70	
	1600 h			-25	
	1800 h				
12 Oct 01	0600 h			70	
	0800 h			230	
	1000 h			290	
	1200 h			278	
	1400 h			140	
	1600 h			25	
	1800 h				
13 Oct 01	0600 h			-25	
	0800 h			100	
	1000 h			250	
	1200 h			310	42
	1400 h			240	
	1600 h			95	
	1800 h				
14 Oct 01	0600 h			43	
	0800 h			80	
	1000 h			245	
	1200 h			300	
	1400 h			320	
	1600 h			192	
	1800 h			75	
15 Oct 01	0600 h			68	
	0800 h			-25	
	1000 h			75	
	1200 h			260	
	1400 h			337	
	1600 h			300	
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 16 - 20 October 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
16 Oct 01	0600 h			200	
	0800 h			-25	
	1000 h				
	1200 h			170	
	1400 h			340	
	1600 h			345	
	1800 h				
17 Oct 01	0600 h				
	0800 h				
	1000 h				
	1200 h				
	1400 h			320	
	1600 h			355	
	1800 h				
18 Oct 01	0600 h			180	
	0800 h	25		-15	
	1000 h		241	-25	
	1200 h		340	230	
	1400 h				
	1600 h				
	1800 h				
19 Oct 01	0600 h		250		
	0800 h	98	120	365	
	1000 h		45	270	
	1200 h		-25	65	
	1400 h		235	-25	
	1600 h		337	125	
	1800 h		330	330	
20 Oct 01	0600 h		330		
	0800 h		256	325	
	1000 h		40	120	
	1200 h		-25	-25	
	1400 h		150		
	1600 h		280	270	
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 21 - 25 October 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
21 Oct 01	0600 h		340	346	
	0800 h		287	327	
	1000 h		150	176	
	1200 h		-21	-20	
	1400 h		92	-20	
	1600 h		200	124	
	1800 h		300		
22 Oct 01	0600 h			319	
	0800 h		310	320	
	1000 h		180	210	
	1200 h		15	20	
	1400 h		-20	-25	
	1600 h		175	135	
	1800 h		275		
23 Oct 01	0600 h		254	277	
	0800 h		300		
	1000 h		222	235	
	1200 h		40	75	
	1400 h		-18	-25	
	1600 h		110	65	
	1800 h			208	
24 Oct 01	0600 h		170	190	
	0800 h		281	278	
	1000 h		245	252	
	1200 h		128	127	
	1400 h		20	10	
	1600 h		58	25	
	1800 h		154	120	
25 Oct 01	0600 h		140	140	
	0800 h		230		
	1000 h		249	205	
	1200 h		160		
	1400 h		80		
	1600 h		39	10	
	1800 h		99		

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 26 - 30 October 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
26 Oct 01	0600 h		92	70	
	0800 h		188	180	
	1000 h		232	232	
	1200 h		217	225	
	1400 h		145	135	
	1600 h		50	40	
	1800 h		58		
27 Oct 01	0600 h		48	30	
	0800 h		174	100	
	1000 h		223	213	
	1200 h		200	205	
	1400 h		70	200	
	1600 h		41	85	
	1800 h		32		
28 Oct 01	0600 h		38	8	
	0800 h				
	1000 h			175	
	1200 h		229	250	
	1400 h		140		
	1600 h		42	137	
	1800 h			30	
29 Oct 01	0600 h		58	45	
	0800 h		30	-10	
	1000 h		120	100	
	1200 h		235	235	
	1400 h		265	275	
	1600 h		120	195	
	1800 h		75		
30 Oct 01	0600 h		95	70	
	0800 h		-15	-25	
	1000 h		70	45	
	1200 h		215	200	
	1400 h		280	280	
	1600 h		175	245	
	1800 h		105	100	

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 1 - 5 November 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
1 Nov 01	0600 h		158		
	0800 h		2		
	1000 h		15		
	1200 h		115		
	1400 h		255		
	1600 h		290		
	1800 h		180		
2 Nov 01	0600 h		210		
	0800 h		48		
	1000 h				
	1200 h		120		
	1400 h		215		
	1600 h		300		
	1800 h		245		
3 Nov 01	0600 h		280		
	0800 h		120		
	1000 h		30		
	1200 h				
	1400 h				
	1600 h				
	1800 h				
4 Nov 01	0600 h			330	
	0800 h		140	200	
	1000 h			10	
	1200 h				
	1400 h		128	100	
	1600 h		290	260	
	1800 h		280	378	
5 Nov 01	0600 h				
	0800 h			230	
	1000 h			80	
	1200 h			-25	
	1400 h			15	
	1600 h			200	
	1800 h				

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 6 - 10 November 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
6 Nov 01	0600 h		315	328	
	0800 h		210	300	
	1000 h		99	150	
	1200 h			-25	
	1400 h		10	-25	
	1600 h		150	150	
	1800 h		260	272	
7 Nov 01	0600 h		265		
	0800 h		180		
	1000 h	170	180	310	
	1200 h			210	
	1400 h			20	
	1600 h			-25	
	1800 h			80	
8 Nov 01	0600 h			250	
	0800 h		245	300	
	1000 h	89		250	
	1200 h		107	90	
	1400 h			-25	
	1600 h		35	-10	
	1800 h				
9 Nov 01	0600 h				
	0800 h		258	265	
	1000 h		270	280	
	1200 h		170	170	132
	1400 h			34	89
	1600 h			-25	
	1800 h				
10 Nov 01	0600 h		85	200	
	0800 h		220	270	
	1000 h			240	
	1200 h		180	105	3
	1400 h			-25	
	1600 h				30
	1800 h		40		

Table 23 - continued. Tide gauge readings, in centimeters, at the four sample stations along the Estero Real main channel from 11 - 15 November 2001.

Date	Time	El Chorro	Camilo Ortega	Puerto Morazán	Coop. LAN #1
11 Nov 01	0600 h				
	0800 h		120	168	
	1000 h			248	
	1200 h		272	284	330
	1400 h			126	
	1600 h		70	40	190
	1800 h			-25	
12 Nov 01	0600 h				
	0800 h				
	1000 h			190	
	1200 h			285	
	1400 h				
	1600 h			120	
	1800 h				
13 Nov 01	0600 h				
	0800 h				
	1000 h				
	1200 h			238	
	1400 h			320	
	1600 h				
	1800 h				
14 Nov 01	0600 h		85		
	0800 h			-25	
	1000 h		45	-25	
	1200 h			170	391
	1400 h			310	
	1600 h			305	230
	1800 h				
15 Nov 01	0600 h		235		
	0800 h		50	-10	10
	1000 h			-25	
	1200 h		140	80	210
	1400 h		219		
	1600 h		300		
	1800 h		261		

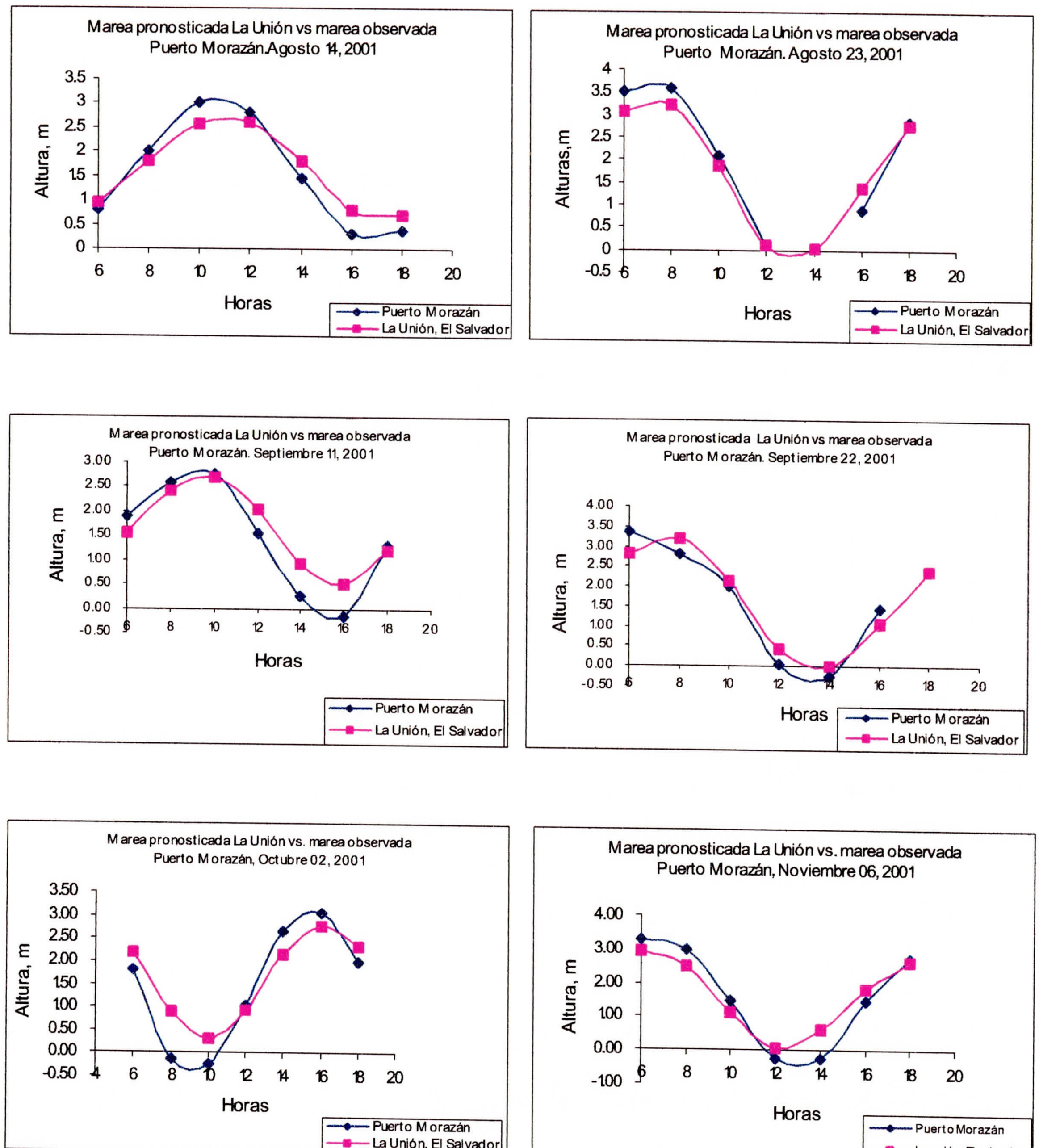


Figure 34. Examples of variation in tidal range and tidal form between La Union, El Salvador (solid squares), and Puerto Morazán, Nicaragua (solid diamonds), during the period August – November 2001. Data for La Union are from tide tables.

SHRIMP POND NUTRIENT BUDGETS

Most shrimp culture in Nicaragua is conducted at a semi-intensive level of management. Stocking rates of shrimp into ponds are low (5-30 PL/m^2). Little or no water is exchanged in ponds (to maintain water quality) during shrimp grow out. And, exogenous nutrients in the form of formulated feeds, and sometimes chemical or organic fertilizers, are added to ponds to increase shrimp productivity. While some of the exogenous nitrogen and phosphorus are assimilated as shrimp flesh, adsorbed by the pond soil, or otherwise metabolized by the pond biota, the remainder of the added nitrogen and phosphorus are discharged to the environment during water exchange events or during pond harvest. Nutrient budgets are developed for aquaculture ponds to quantify inputs and outputs, on a mass basis, of nitrogen and phosphorus. Because shrimp culture in Nicaragua is conducted at two general management levels (semi-intensive private farms, and more extensive cooperative farms), nutrient budgets will be developed for ponds on each type of farm. Nutrient budgets can be used to estimate the quantity of exogenous nutrients discharged to estuaries in the Estero Real system as well as the geographical and temporal distributions of nutrient discharges.

Materials and Methods

This study was carried out on four shrimp farms operating under low input management or semi-intensive management. Three cooperative farms (low-input management) participated along with the UCA-CIDEA farm (semi-intensive management).

The Granja Santa Fe (Figure 35) stocked one 60-ha pond. Shrimp (*Penaeus vannamei*) were stocked at 8.5 PL/m^2 for a 105-day grow out period (Table 24). Shrimp were fed limited quantities of commercial feed (25% crude protein; Table 25). Limited water exchange was employed to maintain water quality.

Figure 35. The Granja Santa Fe 60-ha pond used for the nutrient budget study.

The Granja Edgar Lang (Figure 36) stocked one 22-ha pond for the nutrient budget study. Shrimp were stocked at 5.5 PL/m^2 for the 86-day grow out period (Table 24). Shrimp (*P. vannamei*) were fed limited amounts of commercial feed (25% crude protein; Table 25). Limited quantities of urea fertilizer were applied to ponds (Table 26). Limited water exchange was employed to maintain water quality.

Figure 36. The Granja Edgar Lang 22-ha pond used for the nutrient budget study.

The Granja Rubén Darío (Figure 37) stocked one 49-ha pond for the nutrient budget study. Shrimp (*P. vannamei*) were stocked at 7.6 PL/m^2 and grown for 103 days (Table 24). Commercial feed (25% crude protein; Table 25) was fed to shrimp on a restricted basis. Limited water exchange was employed to maintain water quality.

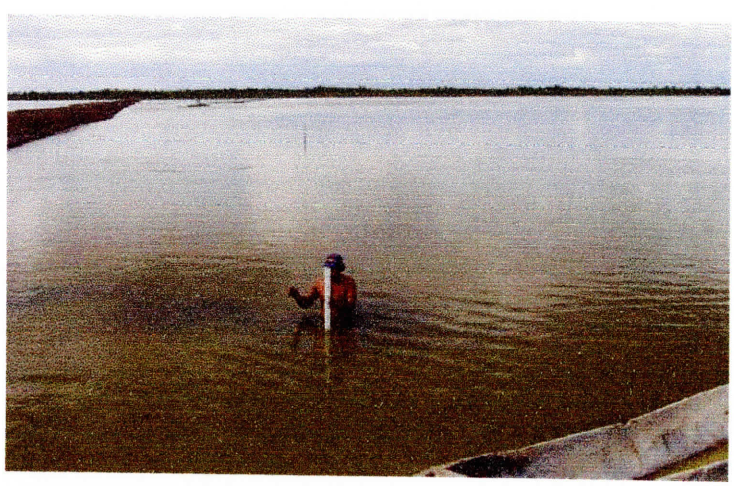


Figure 37. The Granja Rubén Darío 49-ha pond used for the nutrient budget study.

Three 1-ha ponds on the UCA-CIDEA Demonstration Farm (Figure 38) were used for the nutrient budget study. Shrimp (*P. vannamei*) were stocked in all ponds at 5.1 PL/m^2 and grown for 108 days (Table 24). Shrimp were fed a 25%-protein commercial feed (Table 25), and ponds were fertilized with two commercially available chemical fertilizers (Table 26). Water was added to ponds periodically only to replace losses to evaporation and seepage. No other water exchange was used.

Water samples were collected weekly from ponds using a 90-cm column sampler. Sub-samples were collected along an S-shape transect from the deep to the shallow end of the pond and placed into a rinsed 19-L plastic bucket. Once the bucket was full, a 2-L sub-sample was taken using a wide-mouth plastic sample bottle. The bottle was capped tightly and placed on ice in an opaque cooler for transport to the laboratory.

Figure 38. The UCA-CIDEA Demonstration Farm 1-ha ponds used in the nutrient budget study.

Table 24. Stock and harvest dates of ponds in nutrient budget study, pond area and average depth, and number of PLs/m^2 (*P. vannamei*) stocked and PL age.

	Date		Pond		PLs	
Farm	Stock	Harvest	Area (ha)	Depth (m)	Stocked (PL/m^2)	PL Age
Santa Fe	10 May 01	23 Aug 01	60	0.43	8.5	PL-7
Edgar Lang	9 Jun 01	3 Sep 01	22	0.48	5.5	PL-8
Rubén Darío	9 Jun 01	20 Sep 01	49	0.63	7.6	PL-10
UCA-CIDEA A1	1 Aug 01	17 Nov 01	1	0.62	5.1	PL-8
UCA-CIDEA A2	1 Aug 01	17 Nov 01	1	0.61	5.1	PL-8
UCA-CIDEA A3	1 Aug 01	17 Nov 01	1	0.64	5.1	PL-8

Table 25. Proximate analysis, crude protein content, and total quantity of feed per hectare added to nutrient budget study ponds on four farms.

Variable	Santa Fe	Edgar Lang	Ruben Dario Feed 1	Ruben Dario Feed 2	UCA-CIDEA
Moisture (%)	10.76	9.80	18.31	10.55	6.72
Dry Matter (%)	89.24	90.20	81.69	89.45	93.28
Total P (%)	1.30	1.22	1.14	0.90	1.34
Total N (%)	4.16	4.42	3.85	4.37	4.15
Crude Protein (%)	26.0	27.6	23.9	27.3	25.9
Total Feed (kg/ha)	119	26	32	61	A-1: 219 A-2: 205 A-3: 219

Table 26. Fertilizer applied to ponds in nutrient budget study conducted on four farms, nitrogen and phosphate content of applied fertilizers, and total fertilizer per hectare applied to ponds during the study.

Farm	Fertilizer	Nitrogen (%)	P_2O_5 (%)	Total Fertilizer (kg/ha)
Santa Fe	-	-	-	-
Edgar Lang	Urea	46.69	-	4.1
Rubén Darío	-	-	-	-
UCA-CIDEA A1	Nutilake	14.0	3.4	52.2
	Korrector	12.1	1.1	15.9
UCA-CIDEA A2	Nutilake	14.0	3.4	20.4
	Korrector	12.1	1.1	6.8
UCA-CIDEA A3	Nutilake	14.0	3.4	20.4
	Korrector	12.1	1.1	6.8

At the laboratory, water samples were analyzed for NH_3-N, NO_3-NO_2-N, BOD_5, total suspended solids, and settleable solids according to methods given in Standard Methods (APHA, 1998). Salinity and pH were measured potentiometrically. Total nitrogen and total phosphorus were determined simultaneously according to the method given in Grasshoff et al. (1983). Reactive silicate was determined according to the methodology of Strickland and Parsons (1977).

Samples of feed and fertilizers were collected from each farm and analyzed by a private laboratory.

Shrimp populations in each pond were sampled with a cast net beginning about 4 weeks after stocking. At each sampling, 50 shrimp were captured with the cast net and weighed individually to the nearest 0.01 gram. Shrimp were returned to the pond alive. All ponds were harvested by draining. At harvest, shrimp were separated from any by-catch that had entered the pond during initial filling or during a water exchange event. A sample of 300 shrimp per pond was weighed individually to the nearest 0.01 gram. The total weight of shrimp harvest per pond also was determined. The by-catch from each pond was separated by species and a total weight for each species was obtained. One specimen of each by-catch species per pond was selected at random for nutrient analysis. Each specimen was dried at 60 °C, pulverized, and analyzed for nitrogen and phosphorus content by a private laboratory.

Results and Discussion

All ponds in this study received very low quantities of feed (Table 25) and fertilizer (Table 26). It was unnecessary to exchange water in ponds frequently to maintain pond water quality. Water exchange on the cooperative farms ranged from 0 – 17 events, equivalent to a daily water exchange rate that ranged from 0 – 6.5% of pond volume (Table 27). Nutrient budget study ponds on the UCA-CIDEA farm were subjected to two water exchange events per pond, equivalent to exchanging 0.6% of pond volume on a daily basis (Table 27). However, each infrequent water exchange event was relatively large, representing 30 – 40% of the pond volume.

Shrimp in all ponds grew throughout all or almost all of the study (Figures 39 and 40). However, shrimp survival and gross yield were low (Table 28). Shrimp survival ranged from 8 – 27% on cooperative farms, and from 22 – 30% on the UCA-CIDEA farm. Gross yield ranged from 50 – 297 kg/ha on cooperative farms, and from 138 – 215 kg/ha on the UCA-CIDEA farm. Feed conversion ratio ranged from 0.4 – 1.6. A small quantity of by-catch was harvested from each pond in the study (Table 29). The by-catch was composed of eight different species of fish or crustacean, the most common being the fish Popoyote (*Dormitatus latifom*) and the crab (*Platymera gaudichaudii*). The nutrient content of by-catch species is shown in Table 30. Nitrogen content of the by-catch species ranged from 5 – 12% on a dry matter basis, and phosphorus content (on a dry matter basis) ranged from 1 – 3% (Table 30).

Water in the Granja Santa Fe pond was substantially different from water in the remaining ponds (Table 31). Mean weekly total nitrogen was 1.14 mg/L at Granja Santa Fe, but ranged from 0.22 – 0.31 mg/L in the other ponds in the study. Likewise, total phosphorus concentration at Granja Santa Fe averaged 2.6 mg/L, while on the remaining farms mean weekly concentrations were 0.01 mg/L. Mean weekly total ammonia nitrogen was 3.1 mg/L at Granja Santa Fe, and 3.9 mg/L

Table 27. Duration of nutrient budget study on each of four farms, the number of water exchange events that occurred in ponds during the study, the percent of pond volume exchanged per water exchange event, and the percent of pond volume exchanged when the total water exchanged was reported on a daily basis.

Farm	Cycle Duration (d)	Exchange Events (No.)	Exchange/Event (% Pond Volume)	Exchange/Day (% Pond Volume)
Santa Fe	105	17	40.04%	6.48%
Edgar Lang	86	0	0.00%	0.00%
Rubén Darío	103	5	37.82%	1.84%
UCA-CIDEA A1	108	2	32.51%	0.60%
UCA-CIDEA A2	108	2	32.97%	0.61%
UCA-CIDEA A3	108	2	30.31%	0.56%

Table 29. Yield of by-catch, by species, from shrimp ponds on each of the farms that participated in the nutrient budget study.

					UCA-CIDEA		
		Santa Fe	Edgar Lang	Rubén Darío	A1	A2	A3
Common Name	Scientific Name	(kg/ha)					
Bugucha	?	0.01	-	-	-	-	-
Corvinilla Blanca	*Stellifer furthii*	0.03	0.05	0.06	-	0.27	-
Popoyote	*Dormitatus latifom*	0.33	0.01	0.01	0.77	0.41	0.36
Jaiba	*Platymera gaudichaudii*	0.37	0.21	0.23	0.36	0.23	2.04
Pico de Oro	?	-	0.03	0.17	0.14	-	-
Sábalo	*Ophisthonema bulleri*	-	0.02	-	-	-	-
Lisa	*Mugil curema*	-	0.10	-	-	-	-
Palometa	*Peprilus snyderi*	-	0.01	-	-	-	-

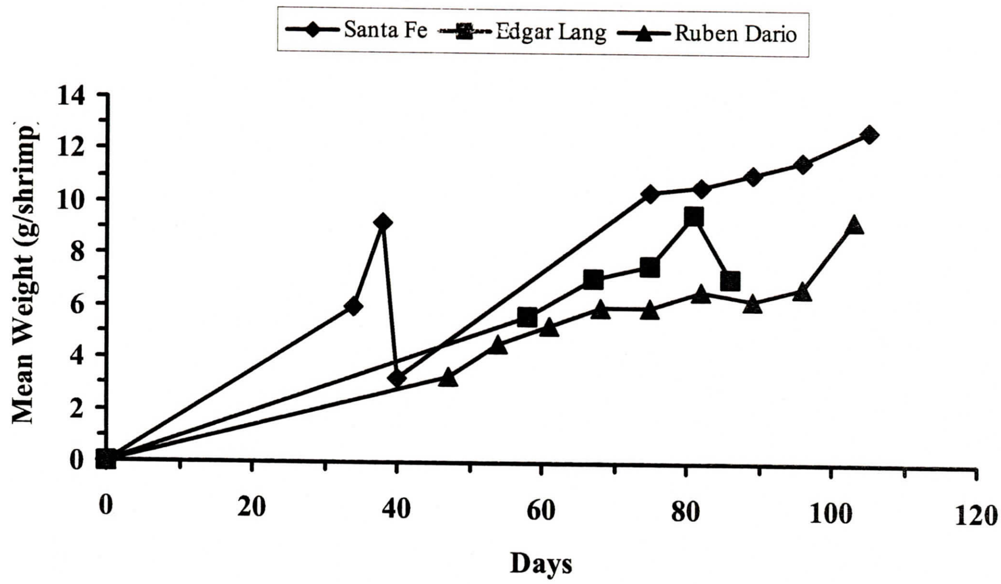


Figure 39. Growth of shrimp (*Penaeus vannamei*) in ponds on three cooperative farms involved in the nutrient budget study.

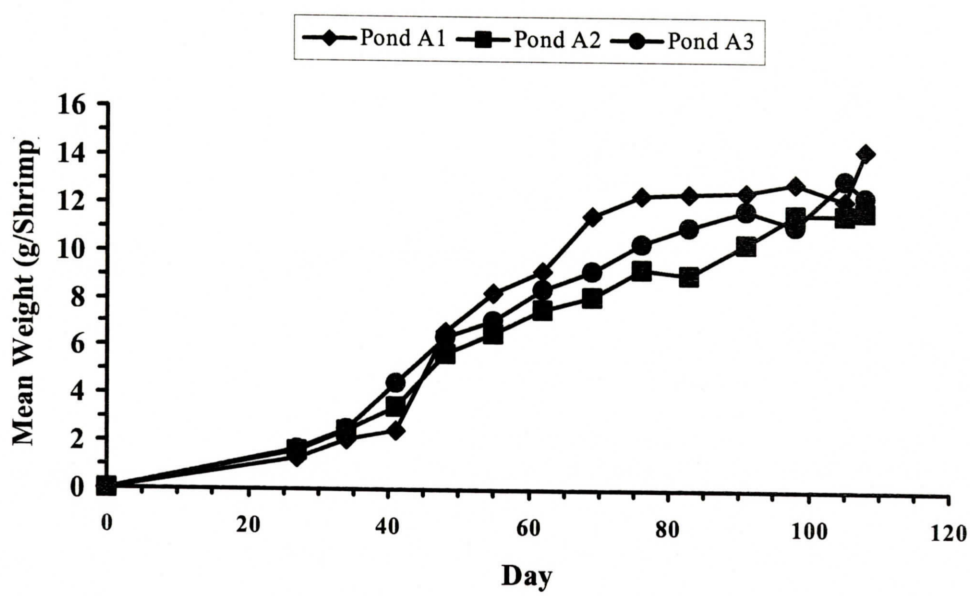


Figure 40. Growth of shrimp (*Penaeus vannamei*) in UCA-CIDEA ponds involved in the nutrient budget study.

Table 28. Gross yield, mean weight, survival, and feed conversion ratio for shrimp (*P. vannamei*) grown in ponds on cooperative farms or on the UCA-CIDEA farm. In addition to shrimp, there was by-catch harvested.

Farm	Gross Yield (kg/ha)	Mean Weight (g/shrimp)	Survival (%)	FCR	By-Catch Yield (kg/ha)
Santa Fe	297	12.8	27.2	0.4	0.8
Edgar Lang	50	7.1	13.0	0.5	0.4
Rubén Darío	58	9.4	8.3	1.6	0.5
UCA-CIDEA A1	215	14.3	29.6	1.0	1.3
UCA-CIDEA A2	143	11.8	23.9	1.4	0.9
UCA-CIDEA A3	138	12.3	22.1	1.6	2.4

at Granja Edgar Lang. The most probable explanation was that the source water for Granja Santa Fe had high nutrient concentrations, which combined with the more frequent water exchange used by this farm, would have introduced nutrients into the pond. Unfortunately, because no samples of inlet water were collected, no estimate can be made of the inlet water quality or contribution of nutrients to the pond by inlet water.

It was impossible to prepare nutrient budgets because initial water samples could not be analyzed for total nitrogen or total phosphorus for delay in receipt of the necessary reagents from overseas. While it was impossible to account for all nutrients introduced into the pond with inlet water, it was possible to estimate nitrogen and phosphorus budgets based on exogenous sources of nitrogen and phosphorus added to the ponds. Inlet water and exchange water were not considered an exogenous nutrient source because fill or exchange water was extract from the estuary and pond discharge was returned to the estuary, often in close proximity to its point of extraction. Feed and fertilizers were the only exogenous nutrient inputs to the production ponds.

Partial budgets for nitrogen and phosphorus were developed for each pond (Table 32). Nitrogen input as feed and fertilizer ranged from 2,97 – 17.68 kg/ha, while the range for phosphorus was 0.79 – 4.68 kg/ha. Harvested shrimp removed 1.49 – 8.78 kg/ha of exogenous nitrogen and 0.18 – 1.03 kg/ha of exogenous phosphorus (Table 32). The shrimp harvest accounted for 34 – 199% of nitrogen added as feed and fertilizer, and for 11 –75% of phosphorus added as feed or fertilizer. Shrimp accounted for a greater percentage of feed and fertilizer nitrogen and phosphorus in cooperative farm ponds because of the lower quantities of added nutrients. In the more intensively managed ponds at the UCA-CIDEA farm, added nutrients were not assimilated as efficiently by shrimp, most likely because of the relatively low gross shrimp yield. Shrimp

Table 30. Nitrogen and phosphorus content (dry matter basis) of by-catch harvested from shrimp ponds in the nutrient budget study.

Common Name	Scientific Name	Farm	Nitrogen (% dry matter)	Phosphorus (% dry matter)
Bugucha	?	Santa Fe	9.83	3.30
Corvinilla Blanca	*Stellifer furthii*	Santa Fe	11.74	2.60
		Edgar Lang	10.50	2.32
		Rubén Darío	10.20	2.66
		UCA-CIDEA A2	9.30	2.30
Popoyote	*Dormitatus latinfom*	Santa Fe	10.55	2.73
		Edgar Lang	11.20	2.40
		Rubén Darío	10.70	2.45
		UCA-CIDEA A1	11.30	2.60
		UCA-CIDEA A2	10.50	2.10
		UCA-CIDEA A3	11.20	2.90
Jaiba	*Platymera gaudichaudii*	Santa Fe	5.93	1.80
		Edgar Lang	6.30	1.34
		Rubén Darío	6.70	1.40
		UCA-CIDEA A1	5.60	1.50
		UCA-CIDEA A2	6.40	1.50
		UCA-CIDEA A3	5.80	1.40
Pico de Oro	?	Edgar Lang	12.10	2.60
		Rubén Darío	9.50	2.75
		UCA-CIDEA A1	11.00	2.80
Sábalo	*Ophisthonema bulleri*	Edgar Lang	10.20	1.70
Lisa	*Mugil curema*	Edgar Lang	7.80	2.65
Palometa	*Peprilus snyderi*	Edgar Lang	9.50	2.80

Table 31. Mean concentrations of water quality variables in samples collected weekly from ponds in the nutrient budget study conducted on four farms.

Farm	pH	Salinity (g/kg)	NH_3-N	Total N	NO_3-N	NO_2-N	Total P	BOD_5	Settleable Solids	TSS	Reactive Silicate
							(mg/L)				
Santa Fe	8.6	16.9	3.11	1.14	0.08	5.23	2.60	1.35	0.06	3.61	2.67
Edgar Lang	8.6	11.0	3.85	0.22	0.65	0.76	0.01	3.45	0.12	0.35	2.32
Rubén Darío	8.6	32.1	0.28	0.28	0.10	0.14	0.01	2.77	0.05	0.72	2.82
UCA-CIDEA A1	8.4	18.2	0.12	0.24	0.15	0.17	0.01	3.00	0.00	0.61	3.61
UCA-CIDEA A2	8.4	19.1	0.14	0.31	0.14	0.17	0.01	3.51	0.00	0.63	4.20
UCA-CIDEA A3	8.4	19.1	0.17	0.31	0.16	0.17	0.01	3.79	0.00	0.61	4.30

Table 32. Partial nutrient budget (on kg/ha basis) for nitrogen and phosphorus in shrimp ponds on four farms in Nicaragua. Budget accounts for nitrogen and phosphorus added as feed and fertilizer, removed as harvested shrimp, and unaccounted for.

	Nitrogen						Phosphorus					
Variable	Santa Fe	Edgar Lang	Rubén Darío	UCA A1	UCA A2	UCA A3	Santa Fe	Edgar Lang	Rubén Darío	UCA A1	UCA A2	UCA A3
Gains												
Feed	4.41	1.02	3.41	8.46	7.95	8.48	1.38	0.28	0.79	2.73	3.68	2.74
Fertilizer	0	1.95	0	9.22	3.09	3.68	0	0	0	1.95	0.77	0.77
Total Gains	4.41	2.97	3.41	17.68	11.04	12.16	1.38	0.28	0.79	4.68	4.45	3.51
Losses												
Shrimp	8.78	1.49	1.73	6.36	4.22	4.08	1.03	0.18	0.20	0.75	0.50	0.48
Total Losses	8.78	1.49	1.73	6.36	4.22	4.08	1.03	0.18	0.20	0.75	0.50	0.48
Un-recovered	(4.37)	1.48	1.68	11.32	6.82	8.08	0.35	0.10	0.59	3.93	3.95	3.03

yield was expected to be higher, perhaps 2 – 3 times greater, which would have improved assimilation of feed and fertilizer nutrients, although more feed would have been added to support growth of a greater shrimp biomass. The un-recovered nitrogen most likely was discharged from the pond at draining, entering the estuary. Phosphorus often is strongly adsorbed by pond mud in aquaculture ponds. The un-recovered phosphorus most likely was adsorbed to pond mud and discharged to the estuary during draining. Because pond mud samples were not collected, the extent of phosphorus adsorption remained unknown.

REFERENCES

American Public Health Association (APHA), 1998. Standard methods for the examination of water and waste water, 20th edition. American Public Health Association, Washington, D.C., 1268 pp.

Grasshoff, K., M. Ehrnhardt, and K. Kremling (Editors), 1983. Methods of seawater analysis. Verlag Chemie, Weinheim, Germany, 419 pp.

Strickland, J. D. H., and T. R. Parsons. 1977. A Practical Handbook of Seawater Analysis. Bulletin 167, Fisheries Research Board of Canada, Ottawa, Canada, 310 pp

Ward, G. H., and B. W. Green. 2001. Effects of shrimp farming on the water quality of El Pedregal and San Bernardo estuaries, Golfo de Fonseca, Honduras. Final technical report to USGS Hurricane Mitch Reconstruction Project Activity B7, Auburn University-USGS Cooperative Agreement 00CRA0010. Auburn University, Alabama, USA. 145 pp.

APPENDICES

Appendix I: List of laboratory equipment and supplies provided by this project as part of the UCA/CIDEA water quality laboratory up-grade.

Item	Description	Quantity
1	Labconco Protector 48 fume hood w/o motor	1 ea
2	Labconco fiberglass blower motor/housing	1 ea
3	Labconco zero pressure weather cap	1 ea
4	Fume hood acid cabinet base	1 ea
5	Fisher Undercounter Refrigerated Incubator	1 ea
6	Mechanical convection oven, general purpose	1 ea
7	Accumet AR15 pH meter kit	1 ea
8	Combination pH electrode, BNC connector	1 ea
9	Fisher model 225 benchtop centrifuge	1 ea
10	24-place fixed angle rotor for 04-978-50	1 ea
11	Buckets for rotor 04-978-52	2 pk 12 ea
12	YSI model 85 DO/salinity meter, 100 ft cable	2 ea
13	YSI model 52 DO meter	1 ea
14	YSI model 5905 self-stirring BOD probe	2 ea
15	Cap membrane kit for YSI DO probes	12 ea
16	Gast vacuum pump	1 ea
17	8-L polypropylene carboy w/spigot	1 cs 6 ea
18	20-L polypropylene carboy w/spigot	1 cs 4 ea
19	2-L rectangular HDPE bottles	4 cs 12 ea
20	Nalgene vacuum filter holder	1 cs 4 ea
21	Whatman GF/F filters	15 pk 100 ea
22	Wheaton Potter-Elvehjem tissue grinder, 15 mL	2 cs 2 ea
23	BOD bottles, 300 mL, numbered 1-24	1 cs 24 ea
24	BOD bottles, 300 mL, numbered 25-48	1 cs 24 ea
25	BOD bottles, 300 mL, numbered 49-72	1 cs 24 ea
26	Barnstead Bantam deionizer 4	1 ea
27	Ultrapure ion exchange cartridge	10 ea
28	Magnetic stirrer	3 ea
29	Magnetic octagonal stir bars, 1.5" L	1 cs 50 ea
30	Stir bar retrievers	2 ea
31	Centrifuge tube, 15 mL, TC	3 cs 12 ea
32	Replacement cushions for buckets 04-978-57	1 pk 12 ea
33	Rectangular polypropylene tank, 11 gal	1 ea
34	Reference weights 1-100 g, ASTM Class 2	1 ea

Appendix I. Continued.

Item	Description	Quantity
35	Weighing dishes, 2.5/2	1 cs 6 pk
36	Beakers, 50 mL	2 cs 4 pk
37	Heavy duty 250 mL beakers	2 cs 4 pk
38	Heavy duty 600 mL beakers	1 pk 6 ea
39	Unitary wash bottles, 4 oz	1 pk 6 ea
40	Unitary wash bottles, 8 oz	1 pk 4 ea
41	Weighing bottles, 50 mL	1 cs 6 ea
42	Brush for 500 mL flasks	6 ea
43	Brush for 1000 mL flasks	6 ea
44	Brush, 12 in.	6 ea
45	Brush, 20 in.	6 ea
46	Centrifuge tube brush	1 pk 12 ea
47	Camel hair brush	1 ea
48	Liqui-Nox detergent, 1 gal	2 cs 4 ea
49	Graduated cylinder, 50 mL	1 cs 12 ea
50	Graduated cylinder, 100 mL	1 cs 12 ea
51	Graduated cylinder, 250 mL	1 cs 6 ea
52	Graduated cylinder, 500 mL	1 cs 4 ea
53	Graduated cylinder, 1000 mL	1 cs 4 ea
54	Graduated cylinder, 50 mL w/stopper	4 pk 4 ea
55	Erlenmeyer flasks, 125 mL	3 cs 4 pk
56	Erlenmeyer flasks, 250 mL	3 cs 4 pk
57	Erlenmeyer flasks, 500 mL	1 pk 6 ea
58	Erlenmeyer flasks, 1000 mL	1 pk 6 ea
59	Filter flask, 250 mL	1 cs 3 pk
60	Filter flask, 500 mL	1 pk 6 ea
61	Volumetric flask HD, 50 mL	2 cs 12 ea
62	Volumetric flask HD, 100 mL	2 cs 12 ea
63	Volumetric flask HD, 250 mL	1 cs 12 ea
64	Volumetric flask HD, 500 mL	1 cs 12 ea
65	Volumetric flask, 1000 mL	2 cs 6 ea
66	Volumetric flask, 2000 mL	1 cs 4 ea
67	Volumetric pipets, 0.5 mL	1 cs 12 ea
68	Volumetric pipets, 1 mL	1 cs 12 ea
69	Volumetric pipets, 2 mL	1 cs 12 ea

Appendix I. Continued.

Item	Description	Quantity
70	Volumetric pipets, 3 mL	1 cs 12 ea
71	Volumetric pipets, 4 mL	1 cs 12 ea
72	Volumetric pipets, 5 mL	1 cs 12 ea
73	Volumetric pipets, 10 mL	1 cs 12 ea
74	Volumetric pipets, 25 mL	2 cs 12 ea
75	Volumetric pipets, 50 mL	2 cs 12 ea
76	Measuring pipets, 1 mL	1 cs 12 ea
77	Measuring pipets, 2 mL	1 cs 12 ea
78	Measuring pipets, 5 mL	2 cs 12 ea
79	Measuring pipets, 10 mL	2 cs 12 ea
80	Measuring pipets, 25 mL	2 cs 12 ea
81	Pipet cleaning set	1 ea
82	Pipet bulb	2 pk 3 ea
83	Repipet dispenser, 5 mL	2 ea
84	Repipet dispenser, 10 mL	1 ea
85	Rack for BOD bottles	3 ea
86	Half-mask respirator, med	2 ea
87	Respirator acid gas filters	10 pk 1 pr
88	Wall-mounted eyewash station	1 ea
89	Stanzoil gloves	1 pk 12 pr
90	Apron	2 ea
91	Cuvets	1 cs 36 ea
92	Sterilizer	1 ea
93	Vacuum tubing	2 pk
94	Kimwipes, 4.5 x 8.5 in	1 cs 60 pk
95	Parafilm M	5 ea
96	YSI carrying case	1 ea
97	Nalgene square polypropylene bottle, 1 L	1 cs 24 ea

Appendix II. Cross-sectional and longitudinal bathygrams for the Estero Real system. Data on individual bathigrams is given in Table 22.

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